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WARTIME REPORT

FULL-SCALE WIND-TUNNEL AND FLIGHT TESTS OF A FAIRCHILD

XR2K-1 AIRPLANE WITH A ZAP FLAP AND UPPER-SURFACE

AILERON-WING INSTALLATION

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and William J. O'Sullivan

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WASHINGTON

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SUMMARY

A Fairchild XR2K-1 airplane equipped with a wing having a full-span Zap flap and upper-surface ailerons was tested in the full-scale wind tunnel and in Plight to determine the characteristics of the flap and the ailerons. The lift, drag, and pitching-moment coefficients of the airplane and the aileron rolling-, yawing-, and hinge- moment coefficients were measured at various flap deflections, The maximum rolling velocity and rolling acceleration, the yawing velocity, the time lag in the aileron response, and the aileron control forces were determined.

The flap, when extended from 0° to 43.0°, increased the maximum lift coefficient from 1.29 to 2.37. Increasing the flap gap from $0.010c$ to $0.037c$ with the flap deflected 43.0° increased the maximum lift coefficient by 0.20 and increased the pitching-m ent coefficient. The ailerons produced satisfactory r ll at all flap deflections but had large hinge moments and produced excessive stick forces. The ailerons had negligible response lag and produced a small erratic favorable yaw. At full flap deflection the aileron control forces exhibited a rever- sal, near the neutral position. The control mechanism of the ailerons was subject both to large deflections under load and great friction,

INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, the National Advisor;? Committee for keronau- tics has conducted tests of a full-span Zap flap and upper-aurfaee aileron-wing installation on a Fairchild XR2K-1 airplane. The tests consist of the measurement, in the full-scale wind tunnel, of the primary aerodynamic

characteristics and, in flight, of those characteristics not readily determined in the wind tunnel, The tests are of the same general nature as previous tests of various flaps and ailerons made on a Fairchild 22 airplane (references 1, 2, and 3). The Fairchild XR2K-1 airplane has a different type engine, greater horsepower, and greater weight than the Fairchild 22 airplane, although it is similar in most other details, The Zap flap employed in this investigation is not the same as the Zap flap of reference 2,

The NACA is conducting a systematic investigation of various lateral-control devices for use with full-span flaps, (See references 4, 5, 6, and 7,) The use of full-span flaps has been chiefly hindered by the unsatisfactory characteristics of the various lateral-control devices used with then, Accordingly, particular attention was paid in this investigation to the characteristics of the upper-surface ailerons.

The wind-tunnel tests are covered in part I of the paper and the flight tests are reported in part II.

AIRPLANE AND WING

The Fairchild XR2K-1 airplane, equipped with a special wing having a Zap flap and upper-surface ailerons, is shown in figures 1, 2, and 3, Dimensions and other characteristics of the airplane as tested are given in table I, The airfoil section, which has been designated by E. F. Zaparka the Z-115 section, is similar to the N-71 airfoil with a slight modification of the upper surface near the trailing edge, The dimensions of the Zap flap are given in figure 4 and in table I. The flap has a curved section and retracts on rollers into the trailing edge of the wing. In the retracted position, the protruding portion of the flap forms the trailing edge of the wing. The flap is operated by a crank mounted on the left side of the cockpit, five turns of the crank being required to deflect the flap to its full, extent, 43.0° from the retracted position; the deflection is directly proportional to the crank motion,

The upper surfaces of the wing near the tips are fitted with the upper-surface ailerons having the appearance shown in figures 1 to 4 and the dimensions given in table I and in figure 4, In the neutral position the

ailerons are continuous with the upper surface of the wing.
The ailerons rotate upward about an axis slightly **above**
and behind the lending edge of the aileron, as shown in
figure 4. The differential motion of the ailerons under
no load is given in figure 5. The nilerons are moved by
cam mechanisms located at the ailerons and operated **by**
control cables from the stick.

The Fairchild XR2K-1 airplane is normally equipped
with a rectangular wing with rounded tips that has a
span of 32 feet 10 incnes, a chord of 5 feet 6 inches,
and is of N-22 airfoil section. The area of this wing is
171 square feet and its weight is approximately 200 pounds.
Lateral control is provided by conventional ailerons of
12-inch (18.2 percent c) chord, which extend across almost
the entire trailing edge of the wing (83 percent b).

In comparison witn the wing with which the airplane
is normally equipped, the special wing equipped with the
Zap flap and the upper-surface ailerons is 17.25 percent
smaller in area, 0.6 percent larger in span, and weighs
95.5 percent more,

SYMBOLS

C_D drag coefficient of airplane without propeller
and horizontal tail (D/qS_W)

C_{D_0} profile-drag coefficient of wing (D_0/qS_W)

C_{h_a} resultant aileron hinge-moment coefficient
$(H_a/qS_a c_a)$

C_L lift coefficient of airplane without propeller
and horizontal tail (L/qS_W)

C_l' aileron roiling-moment coefficient about wind
axis (L'/qbS_W)

$C_{mc.g.}$ pitching-moment coefficient about center of grav-
ity of airplane without propeller and horizontal
tail $(M_{c.g.}/qc^2b)$

$C_{m_{c/4}}$ pitching-moment coefficient about quarter-chord point of airplane without propeller and horizontal tail $(M_{\frac{c}{4}}/qc^2b)$

$C_n{}'$ aileron yawing-moment coefficient about wind axis (N'/qbS_w)

D drag of airplane without propeller and horizontal tail

H_a aileron hinge moment

L lift of airplane without propeller and horizontal tail

L' aileron rolling moment **about** wind axis

$M_{c.g.}$ pitching moment of airplane about center of gravity without propeller and horizontal tail

$M_{c/4}$ pitching moment of airplane about quarter-chord point without propeller and horizontal tail,

N' aileron **yawing** moment about wind axis

S_a area of one aileron $(c_a b_a)$

S_w wing **area** with flap retracted

V_i indicated airspeed

V_t **true** airspeed

b wing span

b_a span of one aileron

b_f flap span

c wing chord with flap retracted

c_a aileron chord, measured as shown in **figure 4**

c_f flap chord, measured as shown in figure 4

c_{d_o} local profile – drag coefficient at $5\frac{1}{2}$ feet to right of canter line

p rolling angular velocity about airplane body axis

α_T angle of attack measured with respect to thrust axis

δ_a aileron deflection from neutral position

δ_f flap deflection, measured as shown in figure **4**

$\dfrac{pb}{2V_t}$ helical angle described by wing tip in roll

I – FULL–SCALE WIND–TUNNEL INVESTIGATION

Tests

All the tests on the Fairch' d XR2K-1 airplane with the Zap flap and the upper–surface aileron–wing installation were made with the horizontal tail surfaces and the propeller removed. The primary aerodynamic characteristics of the airplane were obtained for five flap positions, including the closed and the fully extended conditions, over an angle–of–attack range of −15° to 20° at a test speed of approximately 58 miles per hour. Scale effect on the maximum lift was determined over a range of test speeds from 28 to 60 miles per hour for the closed, the three–fifths open, and the fully extended flap positions.

Momentum surveys were made behind the wing to find the profile–drag characteristics for a number of lift coefficients and for two flap settings. Scale effect on the profile drag with the flap retraoted vas measured over a range of test speeds from 28 to 81 miles per hour.

Aileron rolling–, yawing–, and hinge–moment coefficients were obtained at zero rolling velocity for angles of attack and flap settings simulating flight conditions. The stick forces required to hold the ailerons at constant deflection were obtained by means of a control–force recorder and a control–position recorder installed

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in the cockpit; an aileron-position indicator was also installed on the wing at the left aileron. These instruments made it possible to determine not only the actual stick force required but also the aerodynamic hinge moments and the stick forces that would be required if all the friction were eliminated. The control forces required to extend end to retract the Zap flap were measured by a spring scale.

At the conclusion of the tests on the wing with the flap in the original condition, a metal strip 1.4 inches wide (marked A on fig. 4) was removed from the lower wing surface in order to increese the size of the slot through the wing when the flap was fully deflected, Abridged tests at three flap deflections were made for determining the effects of the slot on both the flap and the aileron characteristics. A second modification was made by removing some fabric on the lower surface of the flap trailing edge (marked B on fig. 4) in order to change the curvature at the trailing edge of the flap, With both of these modifications on the airplane, tests were made with the flap in the fully extended e ʌ in the retracted positions.

Results and Discussion

Lift, drag, and pitching-moment coefficients,- The aerodynamic characteristics of the airplane (figs. 6 and 7) show that the maximum lift coefficient increases with increasing flap deflection from 1.29 at $\delta_f = 0^0$ to 2.37 at $\delta_f = 43.0^0$, with the maximum lift for all flap deflections occurring essentially at the same angle of attack. The slope of the lift-coefficient curve is constant throughout the effective angle-of-attack range when the flap is undeflected. With the flap deflected, the slope of the lift-coefficient curve varies. In comparison with the slope for no flap deflection, the slope with the flnp deflected is slightly greater at low lift coefficients and slightly less at high lift coefficients. The increase in slope may be partly attributed to the increase in the effective wing area when the flap is extended, because c_L is calculated using the wing area with the flap retracted. The decreese in slope is caused by the flow breakdown over the upper surface of the flap at high anglee of attack, Scale effect on the maximum lift coefficient at three flap positions is shown in figure 8.

The airplane pitching-moment coefficients about the center of gravity (table I and fig. 4) for the various flap deflections tested are shown in figure 6. Pitching-moment coefficients about the wine quarter-chord point, derived from the curves of figure 6, are shown in figure 9.

The variation of the profile-drag coefficient with the lift coefficient for the zero and the 13.5° flap deflection is shown in figure 10, and the scale effect on the profile-drag coe'fficient for the flap-retracted Condition is shown in figure 11.

Upper-surface aileron characteristics.- The rolling-moment coefficient and the yawing-moment coefficient about the wind axis as well as the resultant aileron hinge-noment coefficient at zero rolling velocity are plotted against the left aileron deflection at various lift coefficients and flap deflections in figures 12, 13, and 14. When the ailerons are under no load, the right and the left ailerons are interconnected up to 3° left stick deflection (-4 left aileron deflection), as shown in figure 5. When the ailerons are under load, this interconnection may be extended to greater left aileron deflections because of the excessive stretch in the control system,

In figures 12, 13, and 14, the aileron rolling- and yawing-moment coefficients are produced by both the left and the right ailerons up to -4° left aileron deflection, and possibly up to slightly larger deflections because of the stretch in the control system under load. At left aileron deflections in excess of ⊔is amount the aileron rolling-moment coefficient and the yawing-moment coefficient are attributed only to the left aileron. Experimental points cannot be given for the resultant aileron hinge-moment coefficients in figure 12 to 15 because it was necessary to measure the moments at the control stick and to correct the moments for variation of the mechanical advantage of the control system with stretch, The aileron hinge-moment coefficients up to -4° left aileron deflection, and possibly up to slightly greater deflections, are likewise attributed to both the left and the right aileron. At left aileron deflections in excess of this amount the resultant hinge-moment coefficients are at-tributed only to the left aileron. The hinge-moment coefficients shown in figures 12, 13, 14, and 15 are based on

the assumption that the moments arise only from the left aileron,

The resultant aileron hinge-moment coefficients for all of the conditions except that with the flap fully extended are similar in that they increase, although irregularly, with increasing aileron deflection. In the condition with flap fully extended a reversal of the moment occurs in the region from -1° to -9° deflection of the left aileron. When the flap is fully deflected, a small opening (0.010c, measured on the lower surface of the wing) occurs between the flap and the wing, This opening tends to increase the pressure on the lower surface of the ailerons at high lift coefficients and to produce thereby a negative aileron floating angle, This floating tendency may exist at other than full flap deflection but was not indicated by the resultant aileron hinge moment, probably because of the interconnection of the ailerons and the excessive friction of the control system. The ailerons not being weight-balanced, except in the neutral position, the resultant hinge moment normally includes the moment due to the weight of one aileron. The resultant hinge-moment coefficients of figures 12 to 15 do not include the weight moment,

In figure 16 is given the stick force required to slowly increase the aileron deflection at various flap deflections. The mean curves of "hysteresis loops" found by increasing and decreesing the aileron deflection are also given, These mean curves represent the approximate forces that would be encountered if all friction were eliminated from the control system provided that the friction and the cable stretch are the same whether increasing or decreasing the aileron deflection. Even in the approximately frictionless condition the control forces were excessive, **(See** reference 8.) Beyond approximately -4° left aileron deflection the forces shown in figure 16 include the weight moment of one aileron,

The aileron rolling-moment coefficients at zero rolling velocity (figs, 12, 13, and 14) showed an increase with increasing aileron deflection and were slightly greater when the flap was deflected. The coefficient is less than would be given by simple sealed ailerons of equal size having upward deflection only (reference 8), Unlike the simple aileron (reference 8), the upper-surface aileron did not exhibit a rapid decrease in the slope of the rolling-moment coefficient curve at about -20°

deflection, A value of $pb/2V_t = 0.07$ has been found (reference 9) to represent satisfactory rolling for pursuit-type airplanes of present-day speeds. If zero angle of sideslip and zero yawing velocity are assumed, the $C_l{}'$ required to give a $pb/2V_t$ of 0.07 is found to be 0.038 for this particular airplane (calculated by reference 10). The maximum measured values of $C_l{}'$ were, in all cases, in excess of this amount.

The yawing-moment coefficients at zero rolling velocity given in figures 12, 13, and 24 are very small at all lift coefficients with the flap retracted. With the flap deflected, the ailerons appear to give edverse yawing moments. Similar results have been noticed in other investigations of upper-surface ailerons (reference 11).

Flap operating forces.- The operating forces required to extend and to retract the flap are given In figure 17 for two lift coefficients at a *test* speed of 58 miles per hour and in one condition with the tunnel not operating. From these curves it was concluded that the air forces tending to extend or to retract the flap are negligible, that the friction of the operating mechanism constitutes the main portion of the operating force and does not vary greatly with the aerodynamic loed on the flap, and that the unbalanced weight of the flap aids in extending the flap and hinders in retracting it.

Flap-gap modifications.- The maximum lift coefficient of the airplane (figs. 7 and 18) was increased for the retracted-, for the three-fifths-extended-, and for the fully extended-flap conditions when the gap between the wing and the flap was enlarged to 0.037c by removal of the metal strip marked A in figure 4. With the flap fully extended the increase in lift coefficient was 0.20. The pitching-noment coefficients were simultaneously increased be-cause a large percentage of the incresse in lift occurred on the flap. The slope of the lift curve *is* about the same as that obtained with the original flap gap, 'but the curve is shifted toward the negative angles of attack. The drag at all lift coefficients was slightly decreased with the enlarged flap gap (figs. 17, 18, and 19). The increase in gap size will probably cause an increese in the reversal of the aileron hinge moment when the flap is fully extended. During the tunnel tests with the stick locked in the neutral position and the flap fully extended, the aerodynamic forces were sufficient to float both ailerons at an angle of approximately $-5°$.

<u>Flap trailing-edge modifications</u>.- The final tests were made on the airplane with a modified trailing edge on the flap together with the increased flap gap (A and B, fig. 4, removed), The maximum lift and pitching-moment coefficients (fig. 20) in this condition were only slightly increaeed over those without the trailing-edge modification. The drag of the airplane was also increased and approximated the drag for the condition without the enlarged flap gap and trailing-edge modification (fig. 19).

II - FLIGHT INVESTIGATION

Tests

Flight tests of the Fairchild XR2K-1 airplane equipped with the Zap flap and upper-surfpee aileron-wing installation were made in order to investigste the characteristics not measurable in the wind tunnel. Among these characteristics are the maximum rolling velocity, the rolling acceleration, the accompanying yaw, and the time lag in the ailerons. These characteristics were measured both with the flap retracted and extended and at various speeds. No flight tests were made with the modified flap gap and the revised flap trailin' edge.

Continuous photographic records of control movements and the resulting behavior of the airplane were obtained by instsllation of the following NACA instruments:

<u>NACA instruments</u>	<u>Items measured</u>
1. Airspeed recorder	Airspeed
2. Control-position recorders	Rudder, elevator, and lateral stick movements; and flap position
3, Angular-velocity recorders	Angular velocity in roll and yaw
4. Two-component accelerometer	Transverse and normal accelerations
5. Control-force recorder	Stick forces required to operate ailerons and elevators
6. Timer	Time

In addition, an aileron-position indicator was placed on the left aileron to permit the reading of actual aileron deflection in flight.

The error in the airspeed recorder resulting from interference **was** not determined. It is judged that the error in dynamic pressure did not exceed 5 percent with the flap extended and was probably less with the flap retracted.

Results and Discussion

Rolling velocity.- The upper-surface ailerons were investigated **by** abrupt rolls made in level flight with rudder and elevator held fixed. The maximum rolling velocity is presented in figure 21 in terms of $pb/2V_t$ **as** a function of the actual aileron deflection. The expression $pb/2V_t$ represents the tangent of the helical angle described by the wing tip in a roll. The angle being small, $pb/2V_t$ may be considered to equal the helical angle in radians. Numerous other tests (reference 9) have shown that **a** value of $pb/2V_t$ of $0.07(4.0^\circ)$ or above at full aileron deflection indicates a satisfactory rolling velocity for pursuit-type airplanes of present-day speeds. The Fairchild XR2K-1 airplane with the normal wing and ailerons nas a value of the helical angle of about 0.075 radian. Figure 21 shows that, with the flap retracted, the upper-surface ailerons gave a helical angle just slightly greater than the minimum of 0.07 radian for satisfactory control, This value, while obtained at full stick deflection, **is** nevertheless at much less than full aileron deflection because of the excessive stretch in the control system under load. It is apparent that, **if** **full** aileron deflection had been realized, much greater values of the helical angle would have been attained.

When the flap *is* in the retracted position, the helical angle increases slightly with decrease of the **lift** coefficient, **as** **shown** in figure 21, The helical angle **is** approximately directly proportional to aileron deflection, This condition is desirable, With the flap fully extended, the helical angle **i s** much greater at **all** aileron deflections than with the flap retracted. Also, at small aileron deflections, a relatively greater helical angle **is** produced than at large aileron deflections. This

result is more pronounced at the lower **speed or** greater
lift coefficient,

Rolling acceleration.- The variation of maximum
rolling acceleration with aileron deflection in abrupt
aileron rolls for several speeds and flap settings **is**
shown in figure **22,** For the Fairchild XR2K-1 airplane
these characteristics appear to be satisfactory. If the
aileron-control system had exhibited **less** stretch under
load, it is likely that the maximum rolling accelerations
would have been greater,

At **all** flap positions in both slow and **abrupt** ail-
eron rolls, the rolling acceleration **began** and remained
in the correct direction, which indicates that there was
no reversal of the rolling-moment coefficient at small
aileron deflections, **as** is sometimes noticed with spoiler-
type ailerons.

Response time.- Because *of* **the** great friction and
stretch *of* the aileron-control system, measurements of
the time between the start of the stick motion and the
beginning of the rolling velocity in abrupt aileron rolls
are pot believed to **be** a true indication of the aileron
response time. The pilot noted no aileron lag and con-
sidered the ailerons satisfactory in this respect,

Yawing characteristics.- In figure **23** are shown two
typical time histories of the yawing velocity in abrupt
aileron rolls with **flaps** ful'ly retracted and with **flaps**
extended, The rolling velocity, the transverse accelera-
tion, and the stick position (aileron control) are also
shown, It *is* to be noticed that the yawing velocity is
seen to be first favorable, then less favorable, some-
times becoming' adverse, and finally becoming and remaining
favorable, In figure 24(a) is shown the maximum **yawing**
acceleration occurring immediately after aileron deflec-
tion, corresponding to that at approximately 0.55 second
in figure **23,** This acceleration was such as to produce
favorable yaw **for all** flap deflections. In figure 24(b)
is shown the magnitude of the yawing velocity at that
time during the **roll** when it was least favorable and in
some cases adverse, corresponding to approximately 1.5
seconds in figure *23,* For want of a better name this
velocity is called the maximum adverseness of yawing ve-
locity, The values fall on either side of aero **and are**
generally small, **As** a result of the **yawing characteris-
tic,** the **angle** *of* **yaw** produced by the ailerons at the
time of the maximum rolling velocity is relatively small,
though favorable,

Aileron contr Ol forces,- Records were obtained of the control force during slow aileron reversals and normally executed S turns with various flap deflections and at various airspeeds. In all cases, the plot of control force against stick deflection gave loops of large area, an indication that the friction of the control system was excessive. 'Phis result confirms the wind-tunnel measurements of the friction shown in figure 16. The magnitude of the stick forces was excessive; in one case with flaps retracted, approximately 40 pounds was required to obtain a stick deflection of 68 percent of maximum at a speed of only 80 miles per hour, In addition, 'because of the stretch in the control system, this stick deflection does not represent the aileron deflection. In some cases, the stretch was so great that a full stick movement resulted in only a 50-percent aileron deflection, If the stretch of the control system is disregarded and the stick deflection is considered to represent aileron deflection, the forces encountered were from four to eight times greater than forces that would be obtained with conventional ailerons on this airplane. With the flaps fully extended there was indication of a reversal of stick force at small aileron deflections; these results confirm those of the resultant hinge-moment-coefficient curve shown in figure 14.

As shown in figure 21, satisfactory aileron control was obtained at about 60 percent aileron deflection, which indicates that the aileron chord could be reduced and that satisfactory control could still be attained at full aileron deflection. This modification would reduce the stick forces, A low-friction control system would be a considerable improvement, By means of a control system that does not stretch under load, full aileron deflection would be attained with less stick motion (fig, 5). This system would permit the use of a greater mechanical advantage and would further reduce the stick forces, If a sufficient reduction of stick forces could not be obtained with these improvements, further reduction could be made by aerodynamic balancing, as, for example, by a paddle-type balance or by other suitable means.

The attainment of satisfactory control-stick forces at full aileron deflection will not eliminate all objectionable characteristics of the upper-surface ailerons used in this investigation. The reversal of the control forces near the neutral position, which was masked to a large extent by the excessive friction of the control system installed for the tests, will probably be easily

noticed in a low-friction control system. The jerk at the neutral position arising from abruptly stopping the motion of one aileron and starting the motion of the other may also become noticeable and objectionable in a low-friction system.

CONCLUSIONS

The tests made in the full-scale wind tunnel with the propeller and the horizontal tail surface removed led to the following results.

1. The Zap flap when extended from 0° to 43.0^o increased the maximum lift coefficient of the airplane from 1.2'9 to 2.37.

2. The maximum. lift and the pitching-moment coefficients Were inc'reased for all flap settings by an increase in the flap gap from 0.010c to 0.037c.

3. A reversal occurred in the resultant aileron hinge moment when the flap was deflected to the position that opened the flnp gap.

4. Large aileron hinge-moment coefficients and excessive stick forces were measured at high aileron angles, but these stick forces are probably, in part, a fault of the particular test installation.

5. The ailerons gave satisfactory rolling-moment coefficients.

6. The yawing-moment coefficients of the upper surface ailerons were very small at all flap deflections and lift coefficients.

The test made in. flight showed the following results:

1. The ailerons produced the minimum satisfactory rolling velocity with the flap retracted and more than the minimum satisfactory rolling velocity with the flap extended, despite the excessive stretch of the control mechanism under load,

2. The time Zag in the response of the ailerons was so small as to be unnoticeable to the pilot,

3.   The yawing characteristics, although slightly irregular, produced a small fsvorable yaw.

4.   The aileron operating forces on the XR2K-1 airplane installation were excessive.

5.   Because the aileron control system **used** in these tests nad excessive friction and was very flexible under load, the results regarding the aileron-control forces cannot be considered as conclusive.

6.   The results indicate **the** necessity for a considerable overlap in the starting and stopping of the upper-surface ailerons; and that the control system **must be** designed with **low** friction and a small amount of stretch.

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      National Advisory Committee for Aeronautics,
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REFERENCES

1 8   Dearborn, C. H., and Soulé, H. A.: Full-scale Wind-
       Tunnel and Flight Tests of a Fairchild 22 Airplane
       Equipped with a Fowler **Flap.**   NACA TN No. 578, 1936.

2.   Dearborn, C. H., and Soulé, H. A.: Full-scale Wind-
       Tunnel and Flight Testa of a Fairchild 22 Airplane
       Equipped with a Zap Flap and Zap Ailerons,   NACA
       TN No. 596, 1937.

3,   Reed, **Warren** D., and Clay, William C,:   Full-Scale
       Wind-Tunnel and Flight Tests of a Feirchild 22 Air-
       plane Equipped with External-Airfoil Flaps.   NACA
       TN No. 604, 1937.

4.   **Rogallo,** Francis M., and Swanson, Robert **S.:**   Wind-
       Tunnel Development of a Pfug-Type Spoiler-Slot
       Aileron for a Wing with a Full-Span Slotted **Flap**
       and a Discussion of Its Application,   NAGA ARR,
       Nov. 1941.

5.   Bogallo, F, M., and Schufdenfrei, Marvin: Wind-
       Tunnel Investigation of a Plain and a Slot-Lip
       Aileron on a Wing with a Full-Span Flap Consist-
       ing of an Inboard **Fowler** and an Outboard Slotted
       Flap. NACA ARR, June 1941.

6.   Bogallo, Francis M., and Spano, Bartholomew S.: Wind-
       Tunnel Investigation of a Plain and a Slot-Lip
       Aileron on a Wing with a Full-Span Slotted Flap.
       NACA ACR, April 1941.

7.   Harris, Thomas **A.,** and Purser, Paul E.:   Wind-Tunnel
       Investigation of Plain Ailerons for a Wing with a
       Full-Span **Flap** Consisting of an Inboard **Fowler** and
       an Outboard Retractable Split Flap, NACA ACR,
       March 1941,

8.   Weick, **Fred** E., and Jones, Robert T.: Résumé and
       Analysis of **NACA** Lateral Control Research.   NACA
       Rep. No, 605, 1937.

9.   Gilruth, R. **R.,** and Turner, W. N.:   Lateral Control
       Required for Satisfactory Flying Qualities Based
       on Flight Tests of Numerous Airplanes.   NACA Rep.
       No. 715, 1941.

10, Pearson, Henry A., and Jones, Robert T.: Theoretical Stability and Control Characteristics *of* Wings with Various Amounts of Taper and Twist. NACA Rep. No. 635, 1938.

11. Soulé, H. A., and McAvoy, W. H.: Flight Investigation of Lateral Control Devices for Use with Full-Span Flaps. NACA Rep. No. 517, 1935.

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TABLE I.— CHARACTERISTICS OF FAIRCHILD XR2K-1 AIRPLANE
WITH ZAP FLAP AND UPPER-SURFACE AILERON
WING INSTALLATION

Wing:

    Area (flap retracted), S_W, square feet , . . . 141.5
    Span, b, feet 33.02
    Chord (flap retracted), c, f' t 4.34
    Aspect ratio 7.71
    Airfoil section (N-71 with slight modification
      of upper surface near trailing edge) . . , . Z-115
    Angle of incidence, geometric, degrees . . . 3.0
    Angle of incidence, of zero-lift chord line,
      degrees , ... 5.0
    Dihedral, degree 0
    Weight, pounds 391

Zap flap:

    Total area, $(0.3645S_W)$, square feet 51.6
    Span (0.974b), b_f, feet 32.16
    Chord (0.376c), c_f, feet · . . . . 1·63
    Angle of flap when fully deflected relative to
      retracted position, degrees 43

Ailerons:

    Area of one aileron behind hinge axis, S_a,
      square feet 8.17
    Span of one aileron $(0.582\frac{b}{2})$, b_a, feet 9.62
    Chord behind hinge axis (0.1956c), c_a, feet , 0.849
    Beutral setting . . . . .flush with
                       ugper wing surface
    Maximum deflection from neutral with 5-inch
      control stick horns ,-
        Right aileron, degrees up . , . . , . . , 41.6
                degrees down 1.0
        Left aileron, degrees up 44.7
                degrees down 0.1

TABLE I. - CONTINUED

Stabilizer:

Area (not including fuselage), square feet. . . 19.4
Area (including fuselage), square feet. **22.0**
Span, feet 9.75
Maximum deflection relative to thrust axis,
   degrees up. 2.8
   degrees down . , . . , . . , . , . , , . . . **3.6**

Elevator (sealed-hinge type):

Area., square feet . . . . , . 10.4
Maximum deflection relative to thrust axis,
   degrees up **24**
   degrees down **35**
Distance from leading edge of wing to elevator
   hinge, feet 14.38

Fin area, square feet **4.8**

Rudder:

Area, square feet 11.3
Maximum deflection, degrees right 27.6
                        degrees left . . , . , . . 25.4

Weighing data:

Weight as generally flown, pounds . , . . ,2040 to **2160**
Center-of-gravity position—
   Back of leading edge of wing (0.258c), feet · 1.121
   Below leading edge of wing (0.730c), feet , . **3.17**
   Above thrust axis, feet 0.17

Engine:

Make . . . . , , . . Warner
Type . . . . seven cylinder, radial
Rated horsepower, brake horsepower at 2050 rpm   145

Propeller:

Make. . . . . Hamilton
Type . , . . , . , , , .two-blade, **fixed** pitch, metal
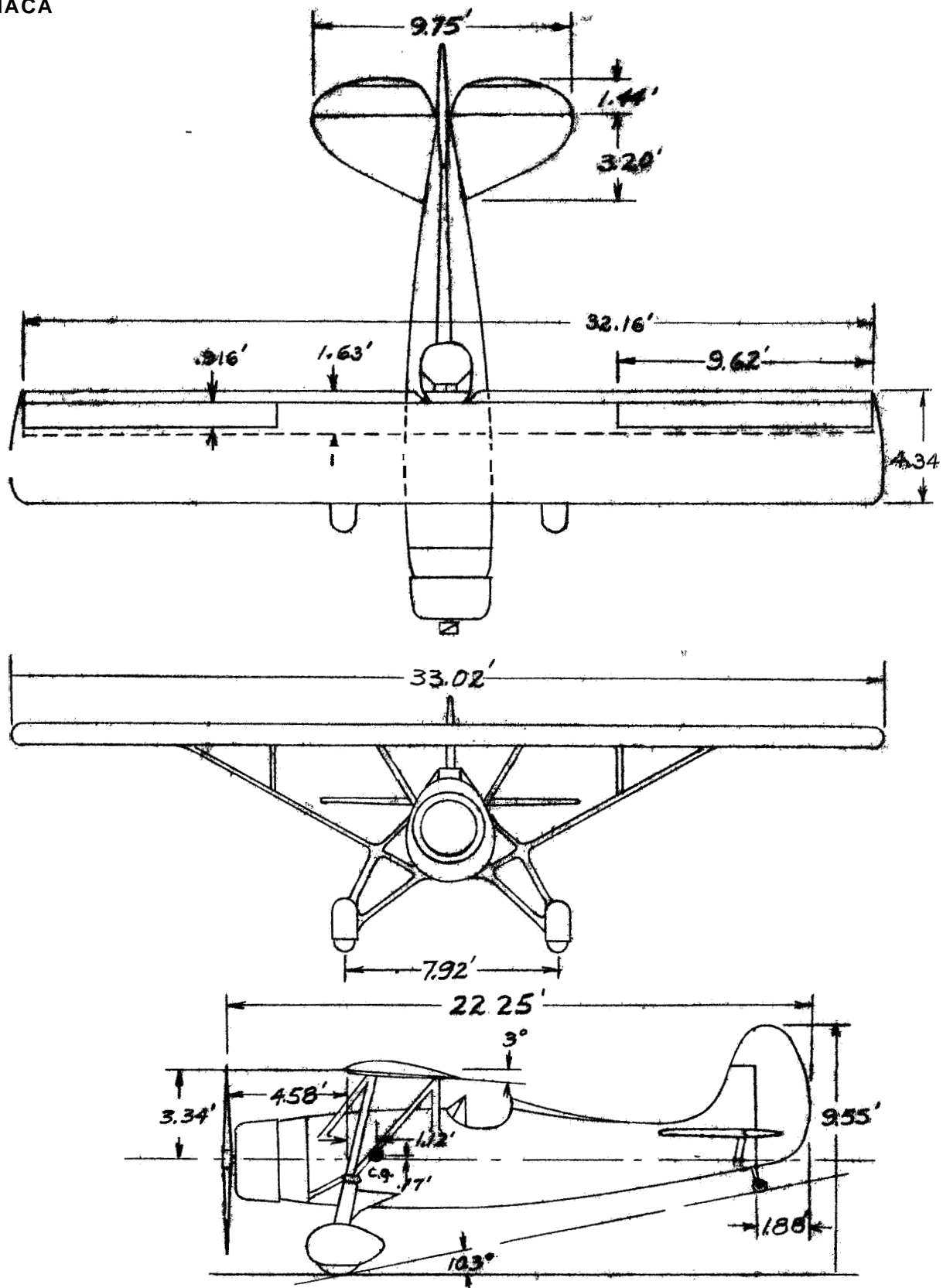
Figure 1. — **Zap-flap** ana upper-surface aileron **wing** installation on the Fairchild XR2K-1 airplane.

Fig. 2

Figure 2.– Fairchild XR2K-1 airplane with Zap flap retracted   a upper-surface ailerons in neutral position.

Fig. 3

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Figure 3.- Fairchild XR2K-1 airplane with Zap flap fully extended and right aileron raised.

Fig. 4

A Metal strip 1.4 inches
   wide removed to
   increase the flap gap
   from .010 c to .037 c

B Circular indentation
   .0672 c wide with a
   maximum depth of
   .0039 c

Figure 4. - Sectional view of wing showing Zap flap, up-
per-surface ailerons, trailing-edge and gap modifica-
tions, and center-of-gravity location of the airplane.
in retracted and fully deflected position
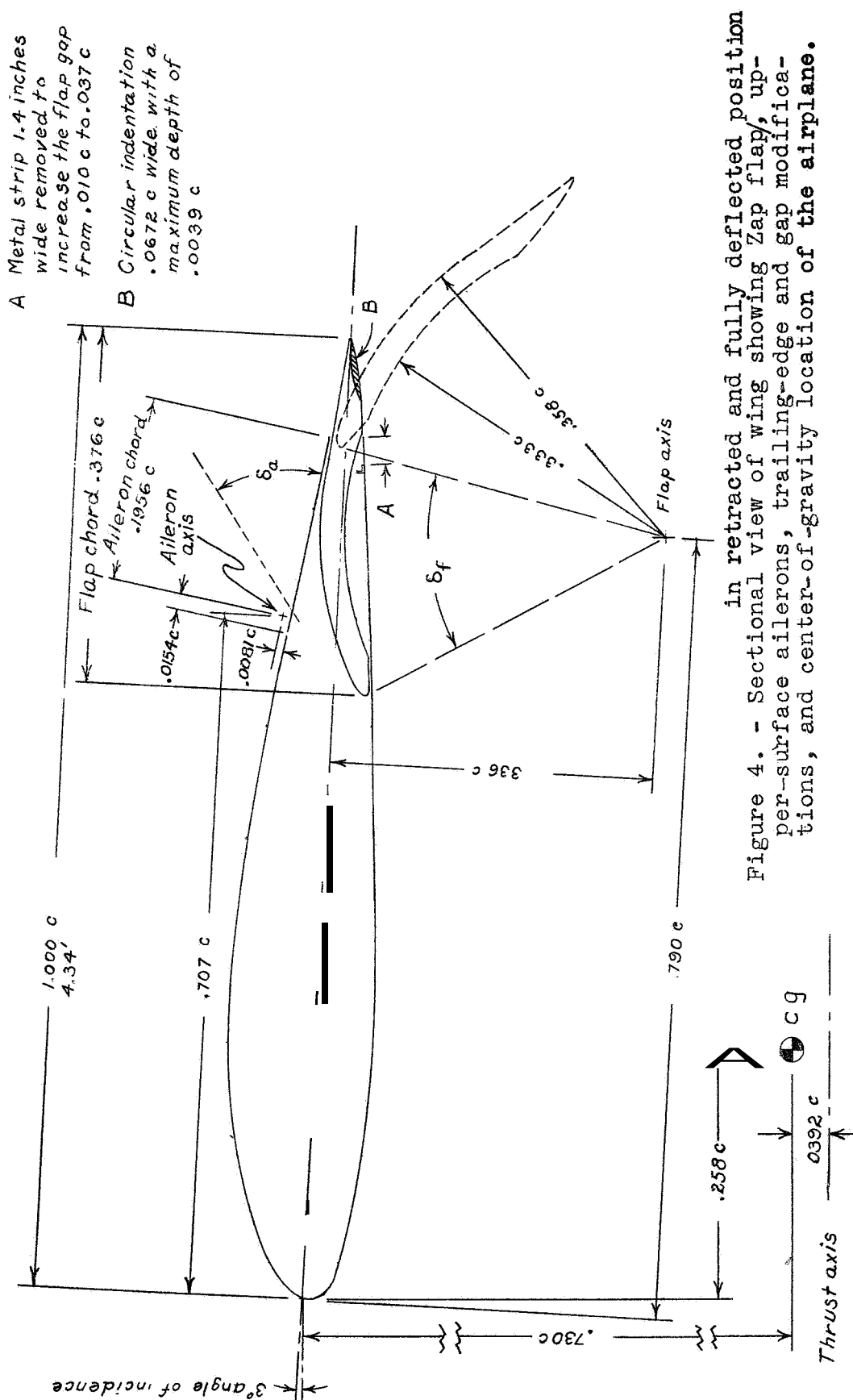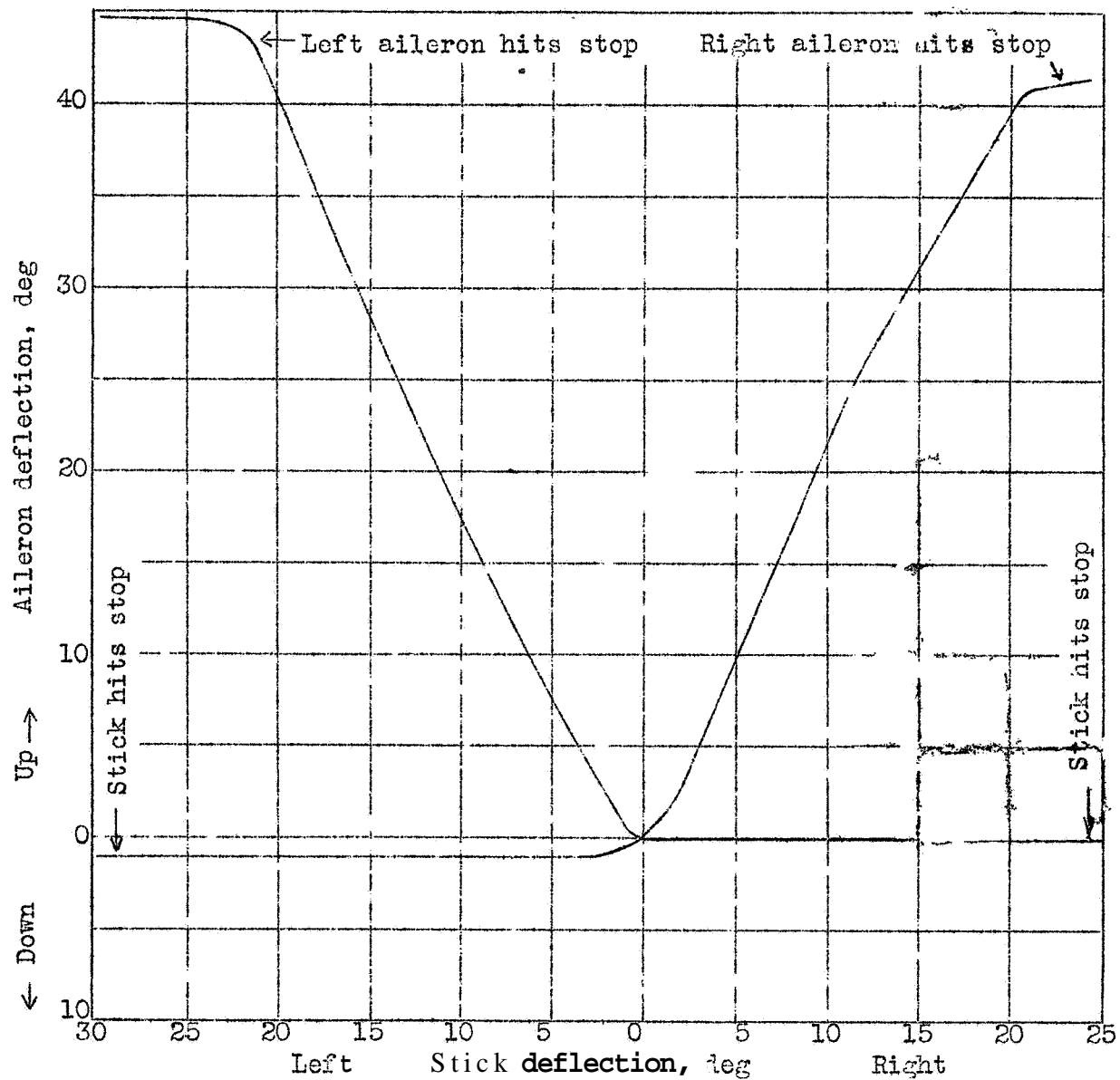
Figure 5.- Simultaneous positions of **right** and **left ailerons** against
control-stick deflection from **neutral,** These **values** apply only
when the ailerons **are under no load.**
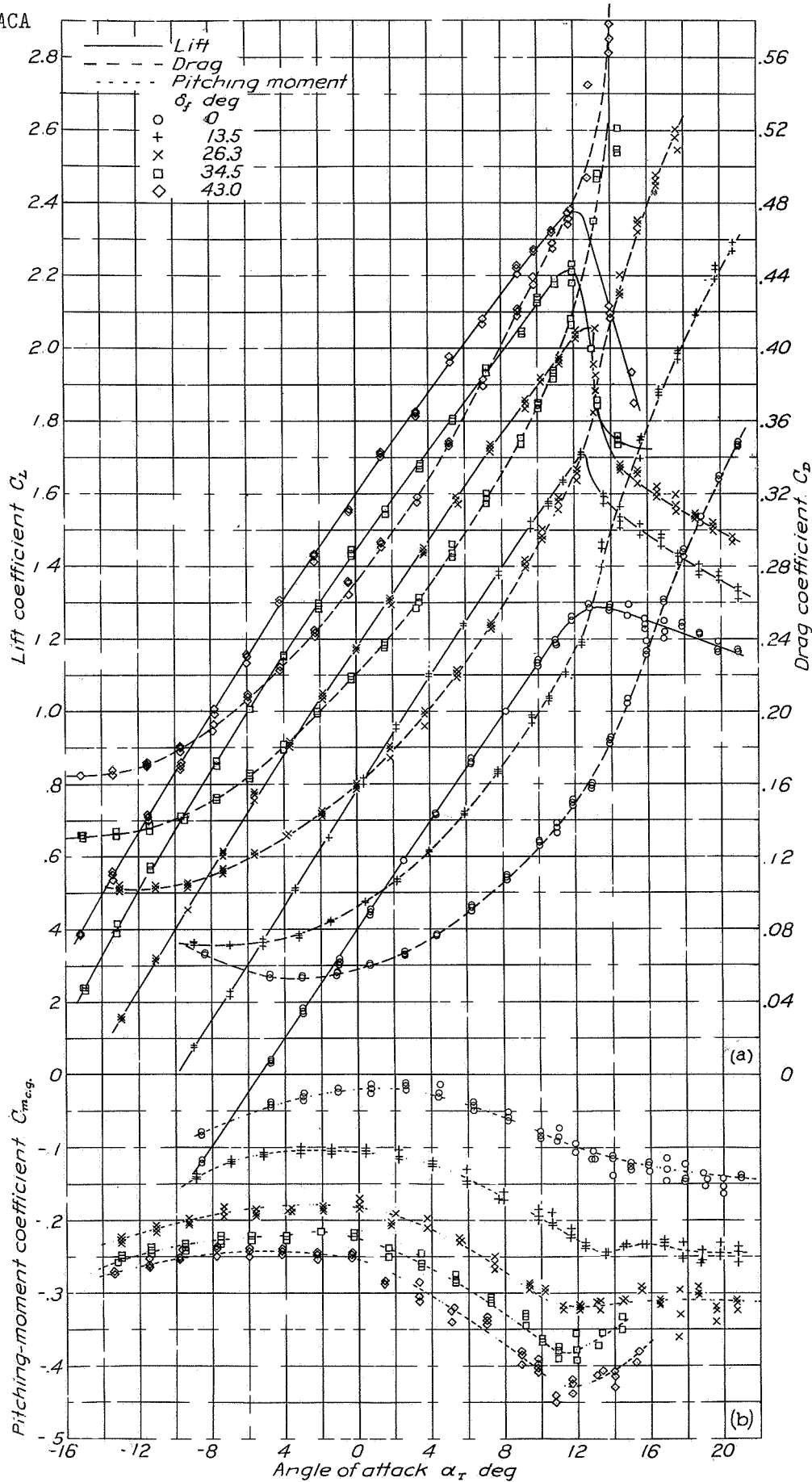
Fig. **6**

Figure.6.-

Aerodynamic characteristics of the Fairchild **XRZK-1** airplane with the zap-flap wing installation. Horizontal tail and propeller removed. Approximate test speed, 58 miles per hour.

Fig. 7
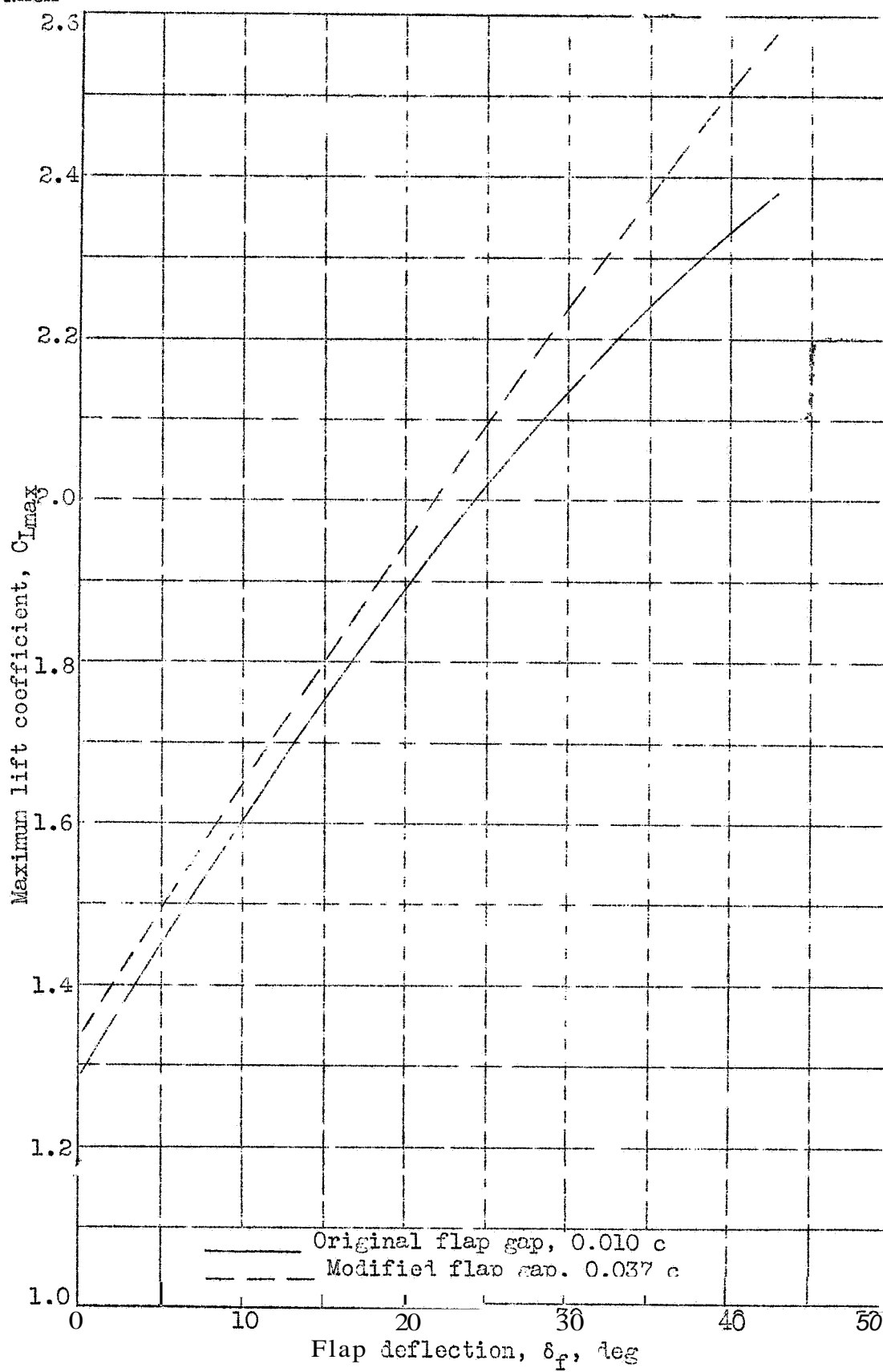
Figure 7.— Variation of the maximum lift coefficient with Zap-flap
deflection and with flap gap.

Fig. 8
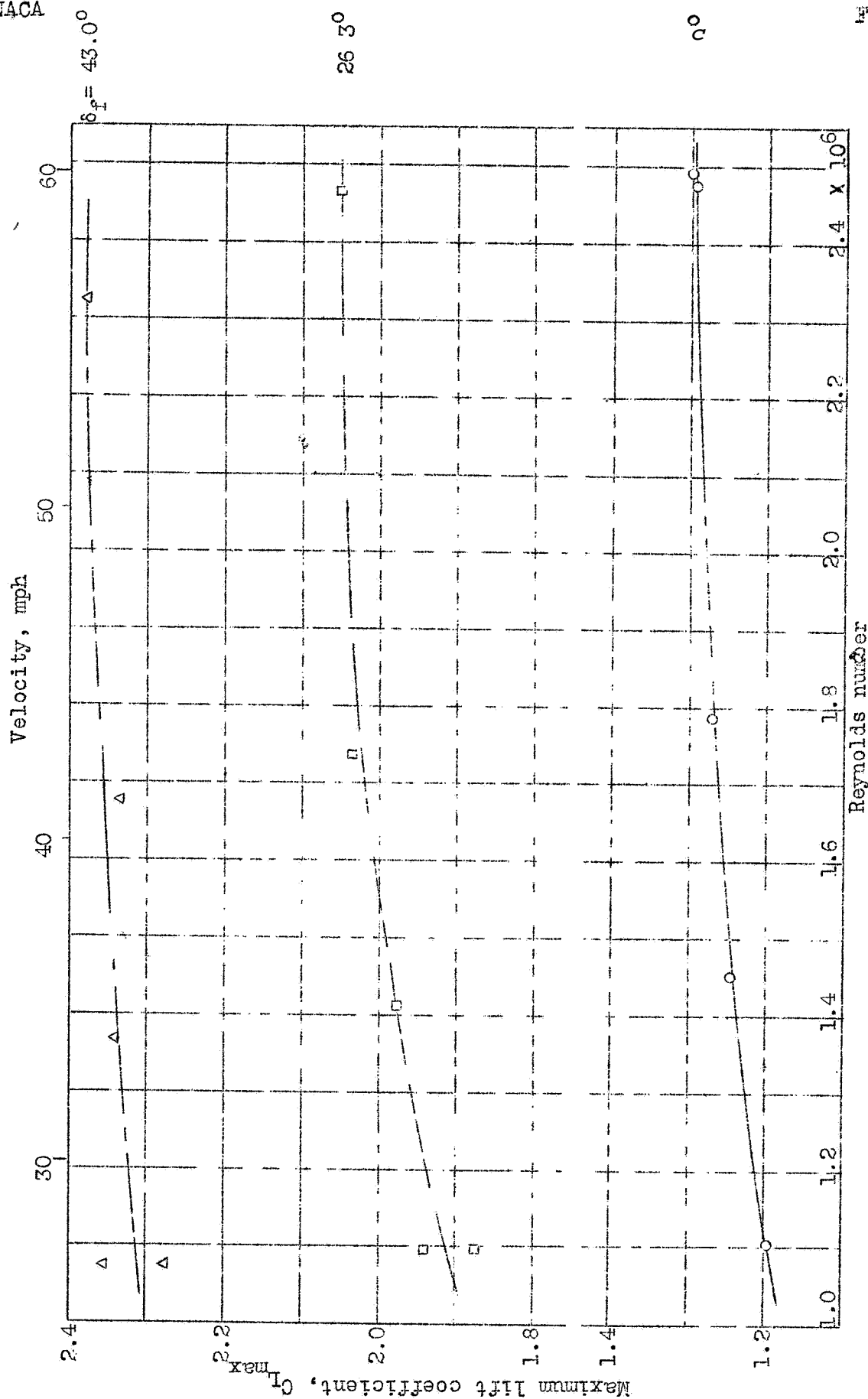
Figure 8.— Scale effect on the maximum lift coefficient with the Zap flap in three positions. Approximate range of test speeds from 28 to 60 miles per hour.
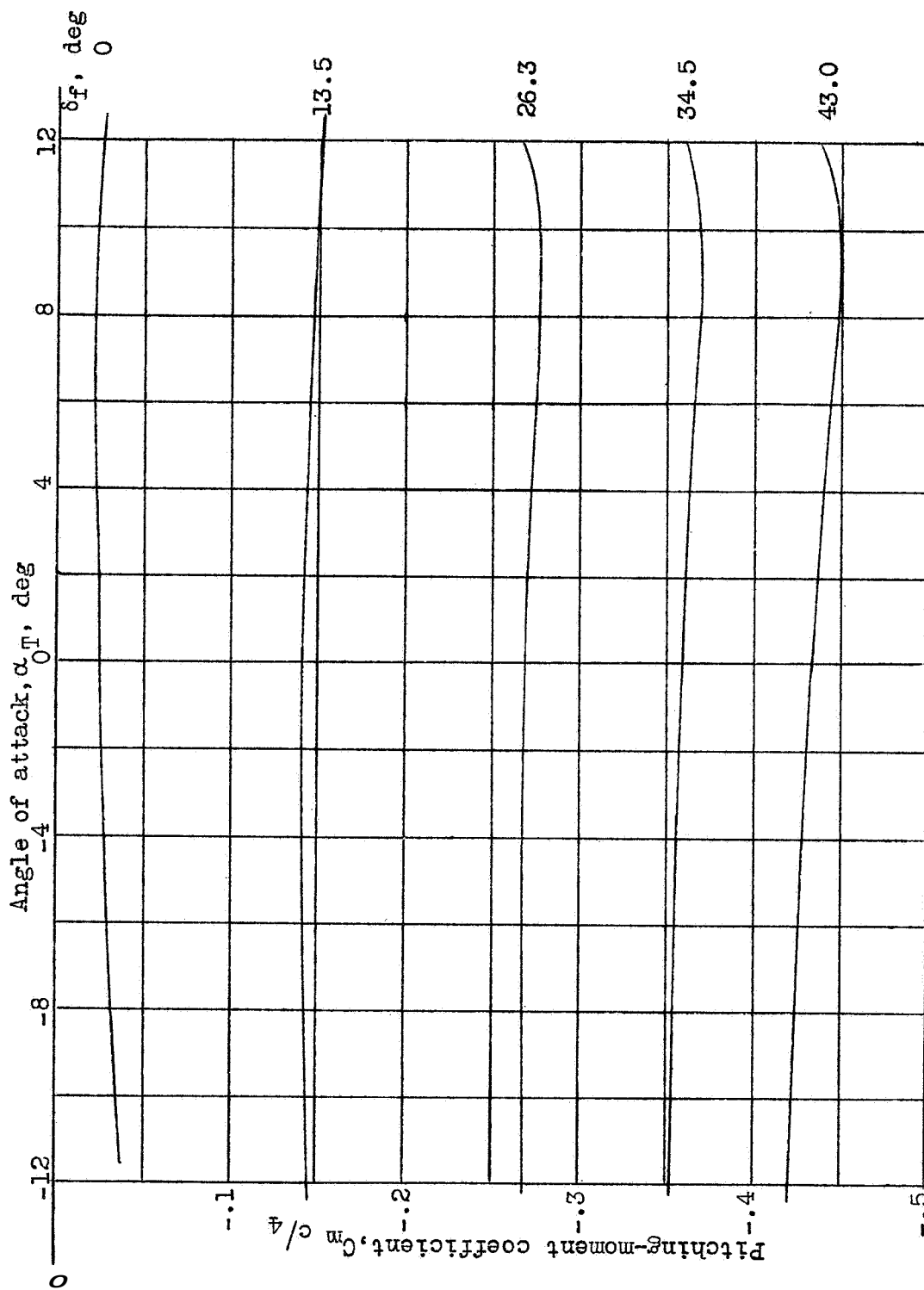
Figure 9.— Pitching-moment coefficients about the quarter-chord point for various flap
deflections of the Fairchild XR2K-1 airplane with the Zap-flap wing installation.
Approximate test speed, 58 miles per hour.
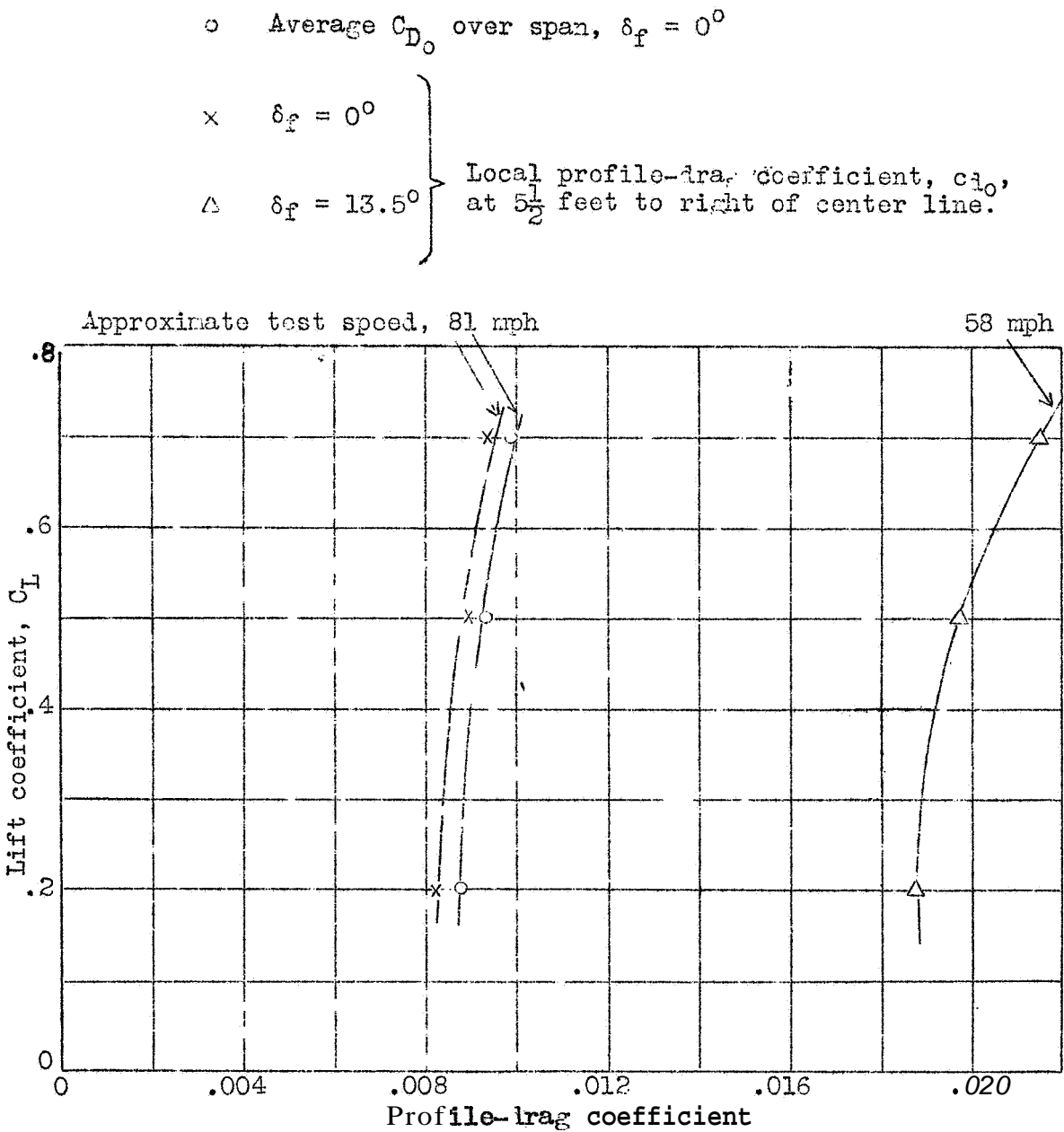
Figure 10.- **Profile-drag coefficients** of tho **Zap-flap wing as measured by**
the monentum method.

Fig. 11

Figure 11.- Scale effect on the profile-drag coefficient of the Zap-flap wing as measured by the momentum method. Measurements made at a section $5\frac{1}{2}$ feet to the right of the center line. Flap deflection, $0°$.

Fig.12

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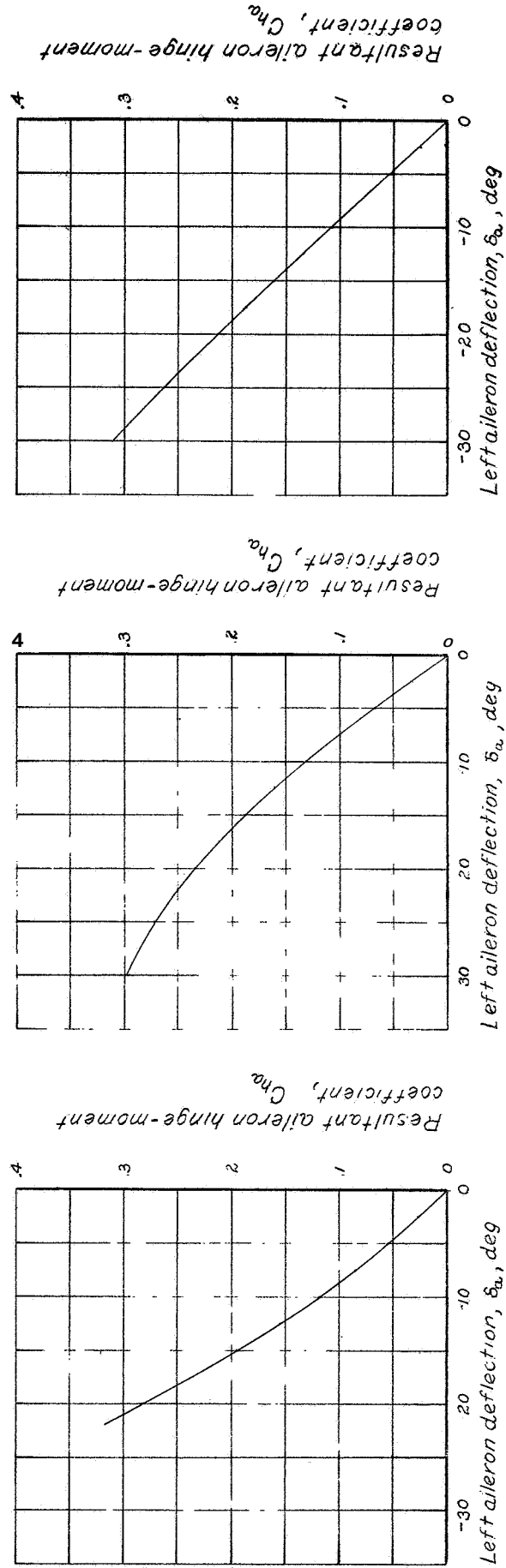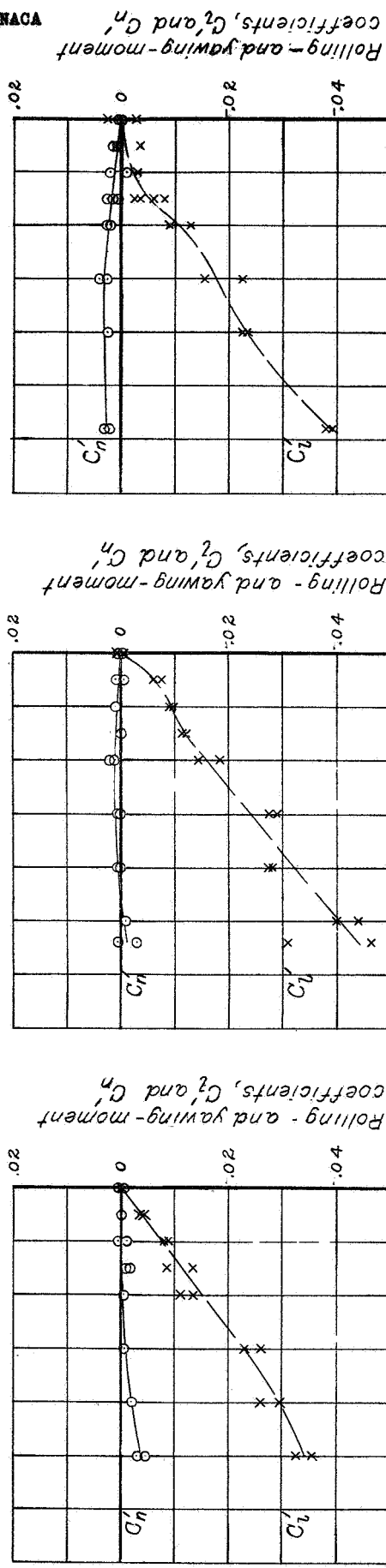
Figure 12. - Aileron rolling- and yawing-moment coefficients about the wind axes and resultant aileron hinge-moment coefficients of the Fairchild XR2K-1 airplane with the Zap-flap wing installation. Approximate test speed, 58 miles per hour; rolling velocity, zero; flap deflection, 0°.

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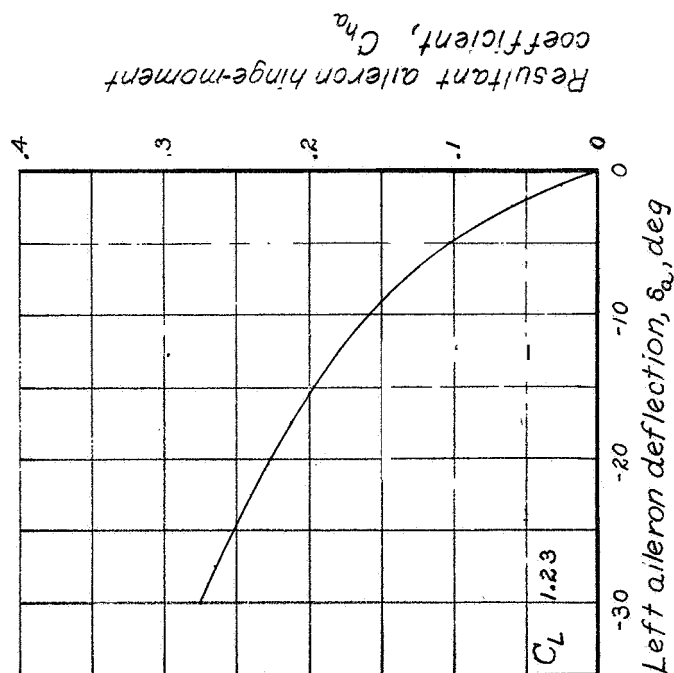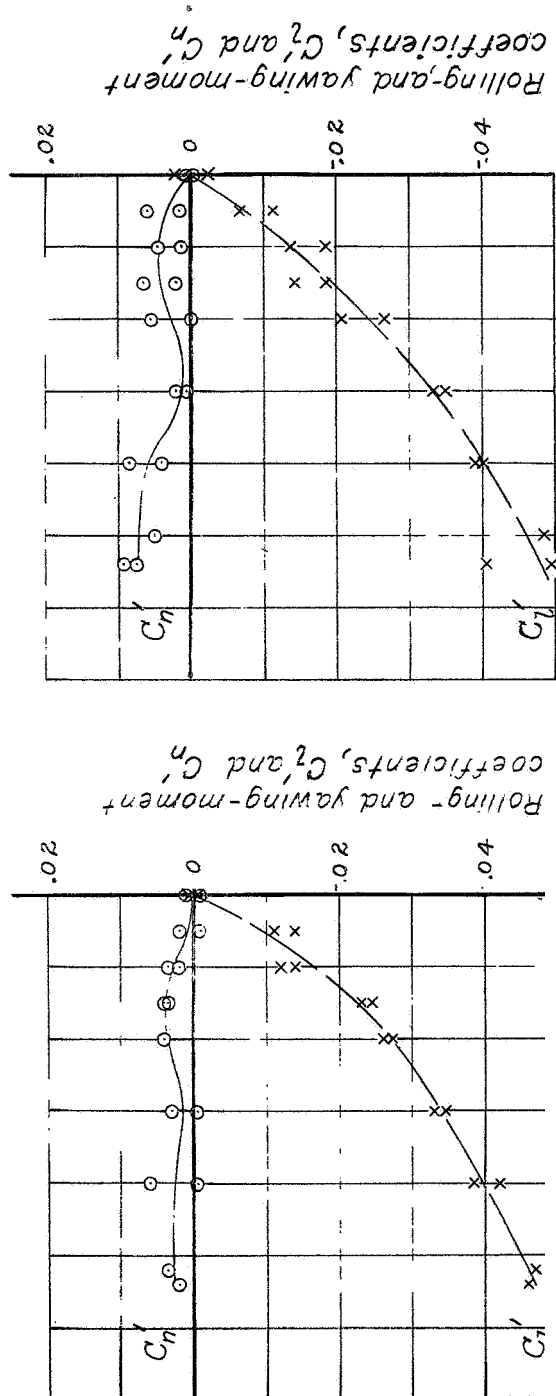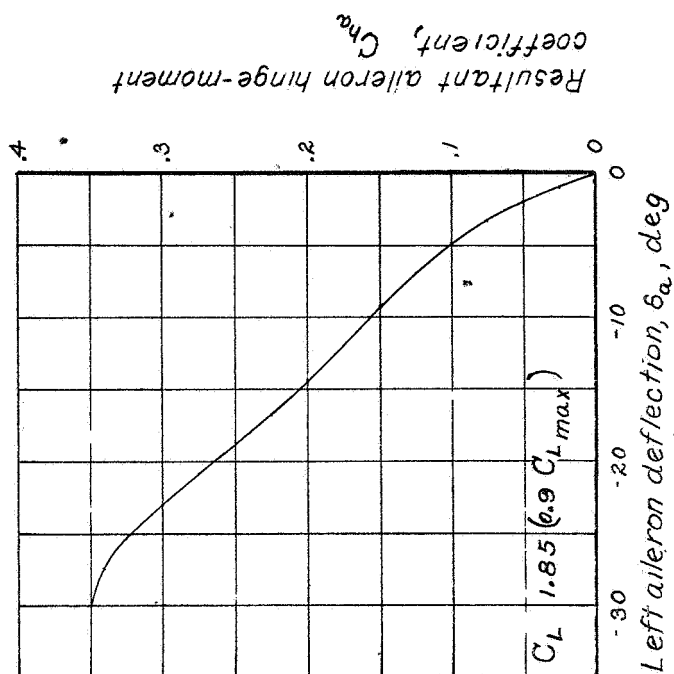
Figure 13. - Aileron rolling- and yawing-moment coefficients about the wind axes and resultant aileron hinge-moment coefficients of the Fairchild XR2K-1 airplane with the Zap-flap wing installation. Approximate test speed, 58 miles per hour, rolling velocity, zero; flap deflection, 26.3°.
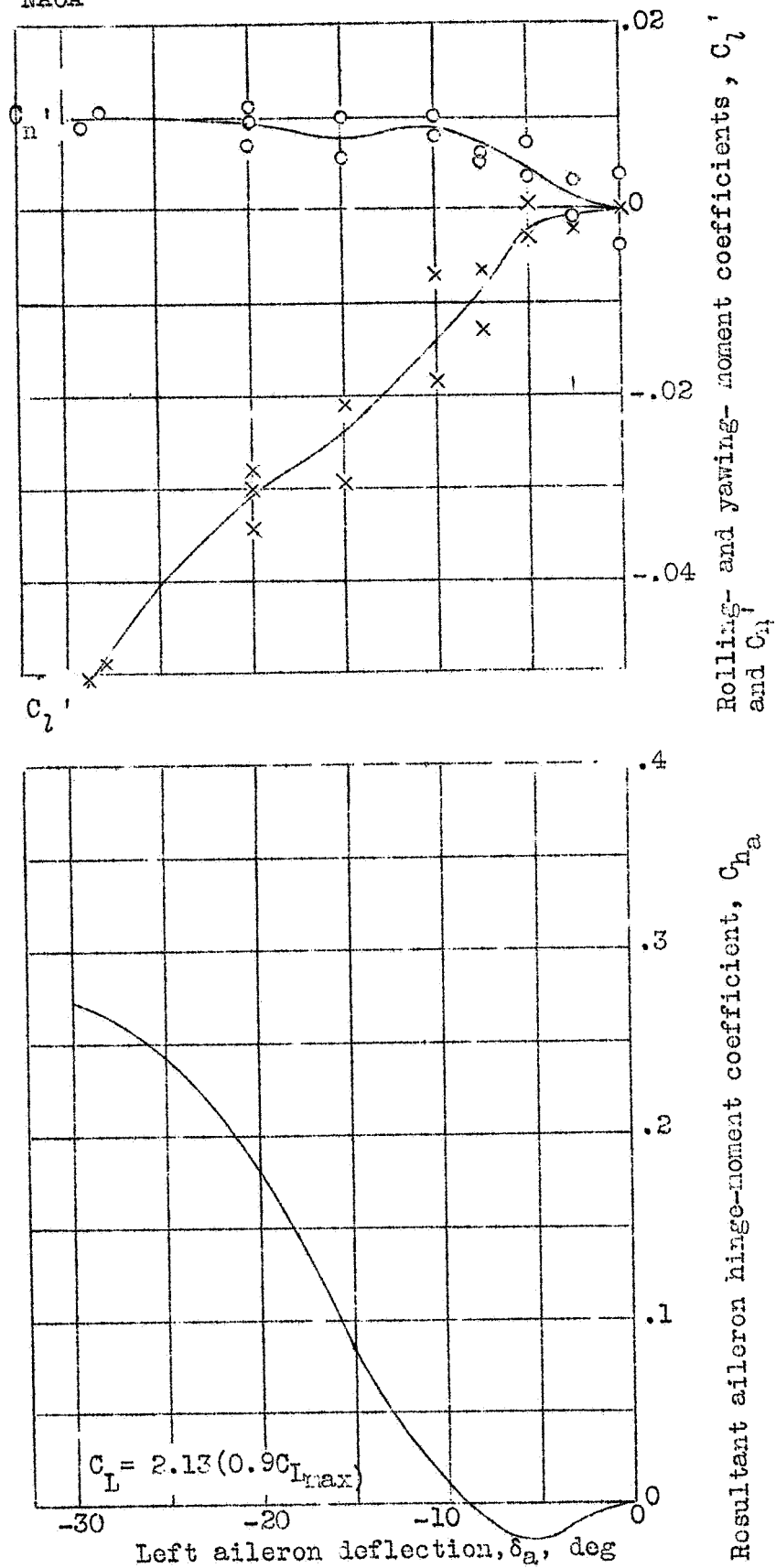
Figure 14.- Aileron rolling and yawing-moment coefficients about the wind axes and resultant aileron hinge-moment coefficients of the Fairchild XR2K-1 airplane with the Zap-flap wing installation.Approximate test speed, 58 miles per hour;rolling velocity,zero;flap deflection, 43.0°.
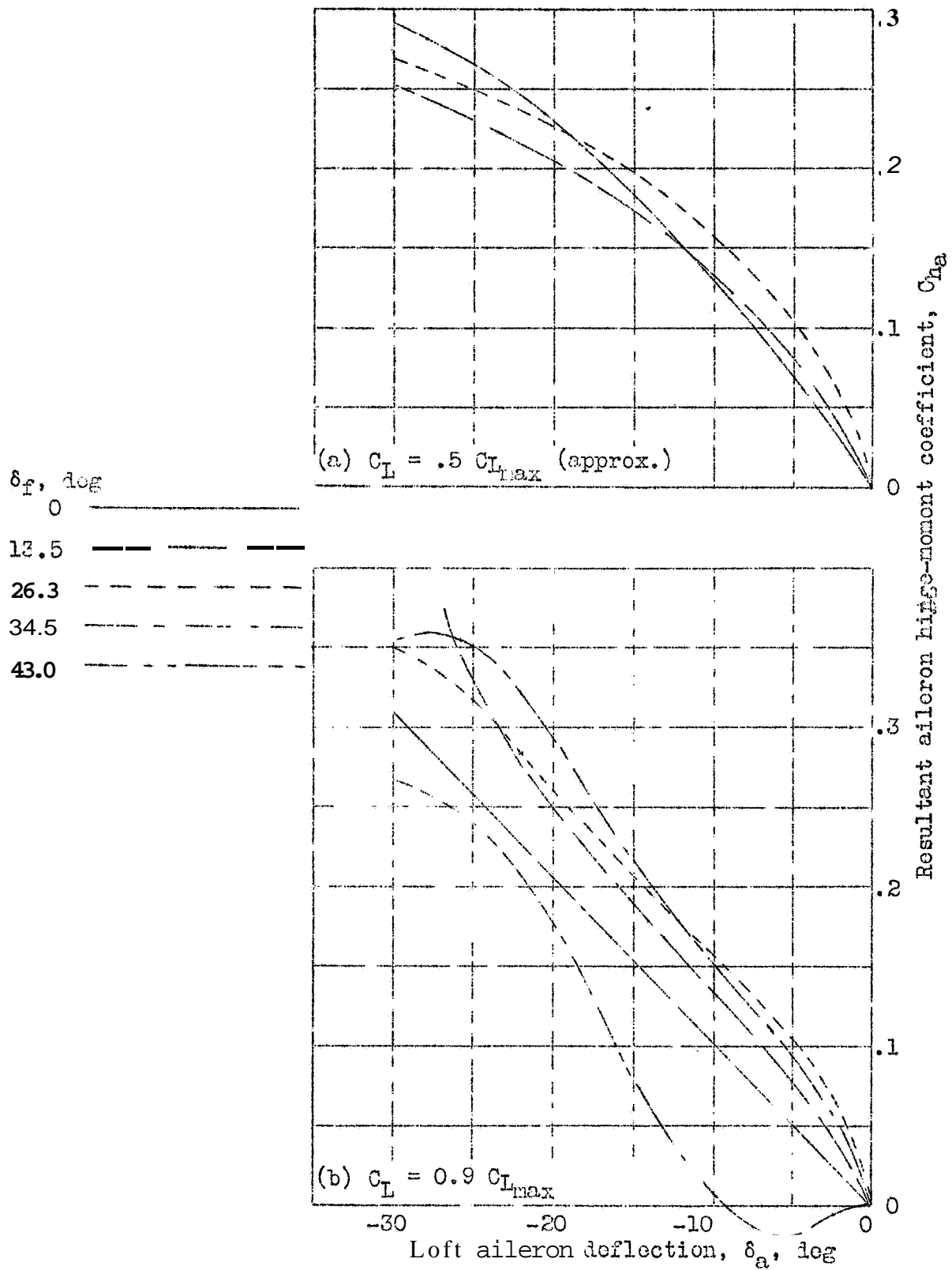
Figure 15.— Comparison of the resultant aerodynamic hinge-moment
         coefficients for the aileron at various flap positions,
Approximate test speed, 58 miles per hour.

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Figure 17. - Control forces required for extending and
retracting the Zap flap.

Figure 16. - Stick forces required to deflect the left aileron with
the flap in various positions. Approximate test speed
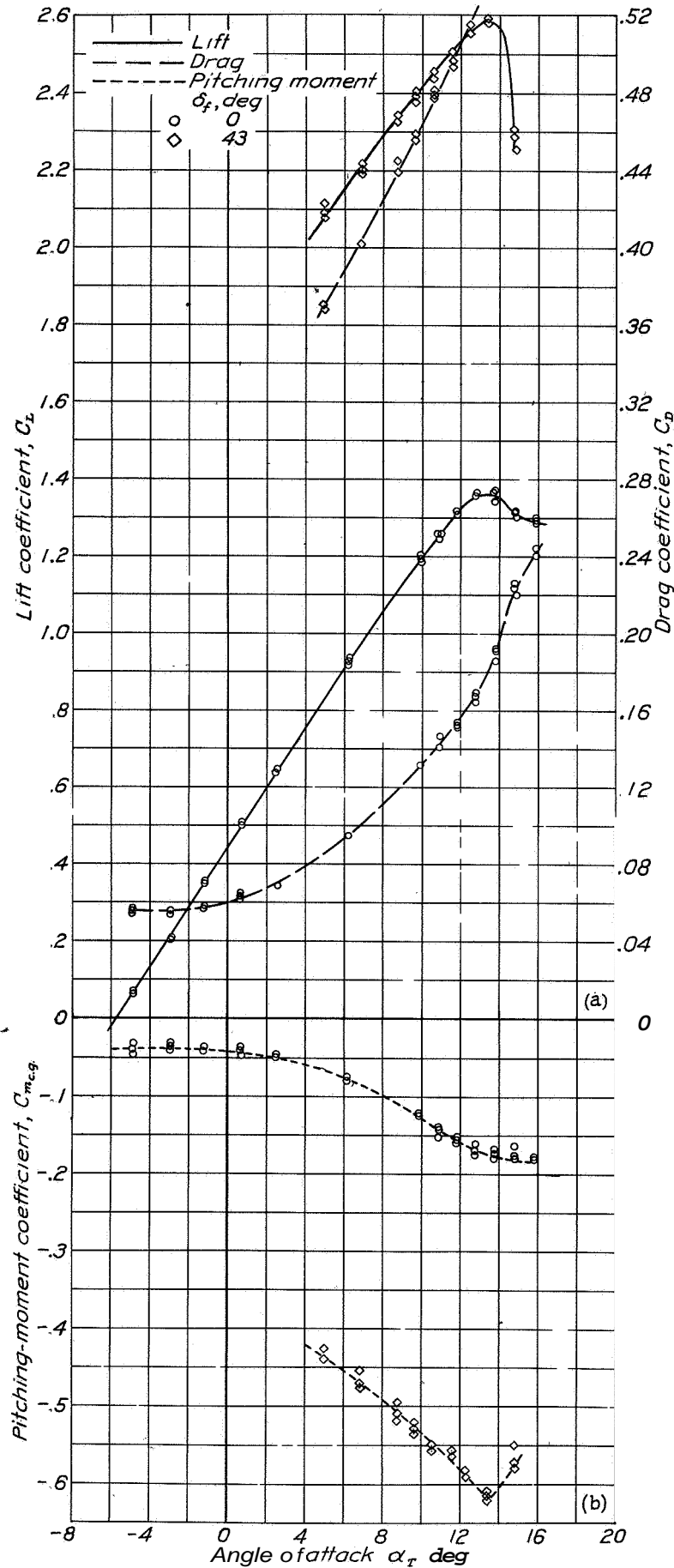58 miles per hour.

Fig. **18**
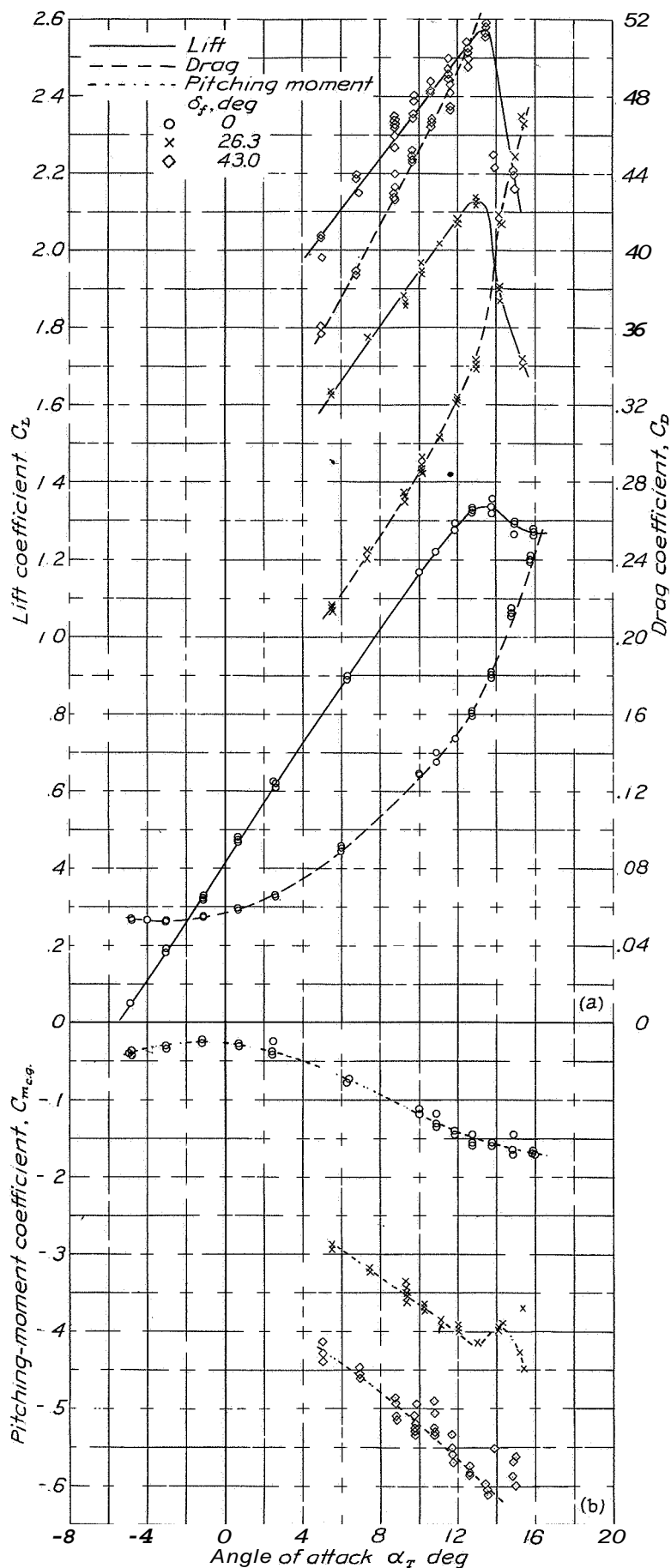
Figure 18.-

Aerodynamic
characteristics
of the Fairchild
XR2K-1 airplane
with the zap-
flap **wing** instal-
lation and an en-
larged flap gap
of 0.037c. Hori-
zontal tail and
propeller re-
moved. Approxi-
mate test speed,
58 miles per
hour.
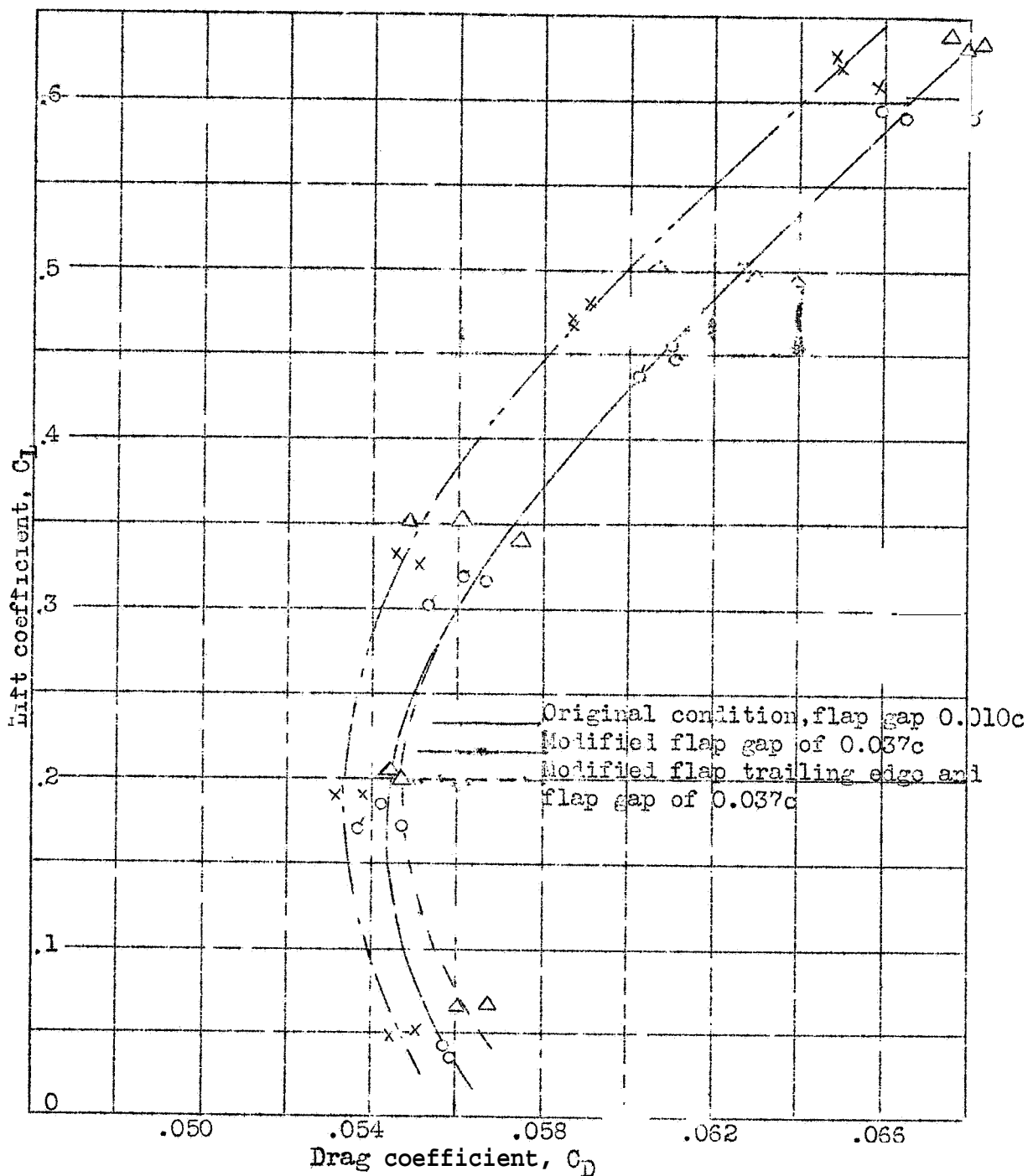
Figure 19.- Lift and drag polar for the Fairchild XR2K-1 airplane with the
Zap-flap wing installation. Test speed, approximately 58 miles
per hour.

Figure 20.-

Aerodynamic
characteris-
tics of the
Fairchild
XR2K-1
airplane with
the zap-flap
installation,
an enlarged
flap gap of
0.037c, and a
modified
trailing
edge on
the flap.
Horizontal
tail and
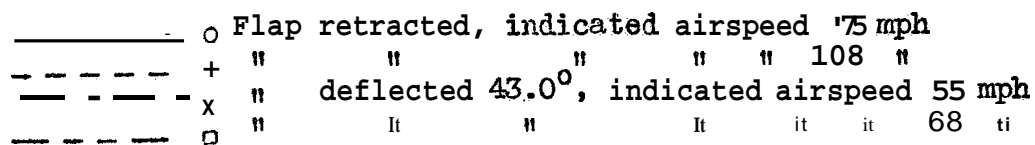propeller
removed,
Approximate
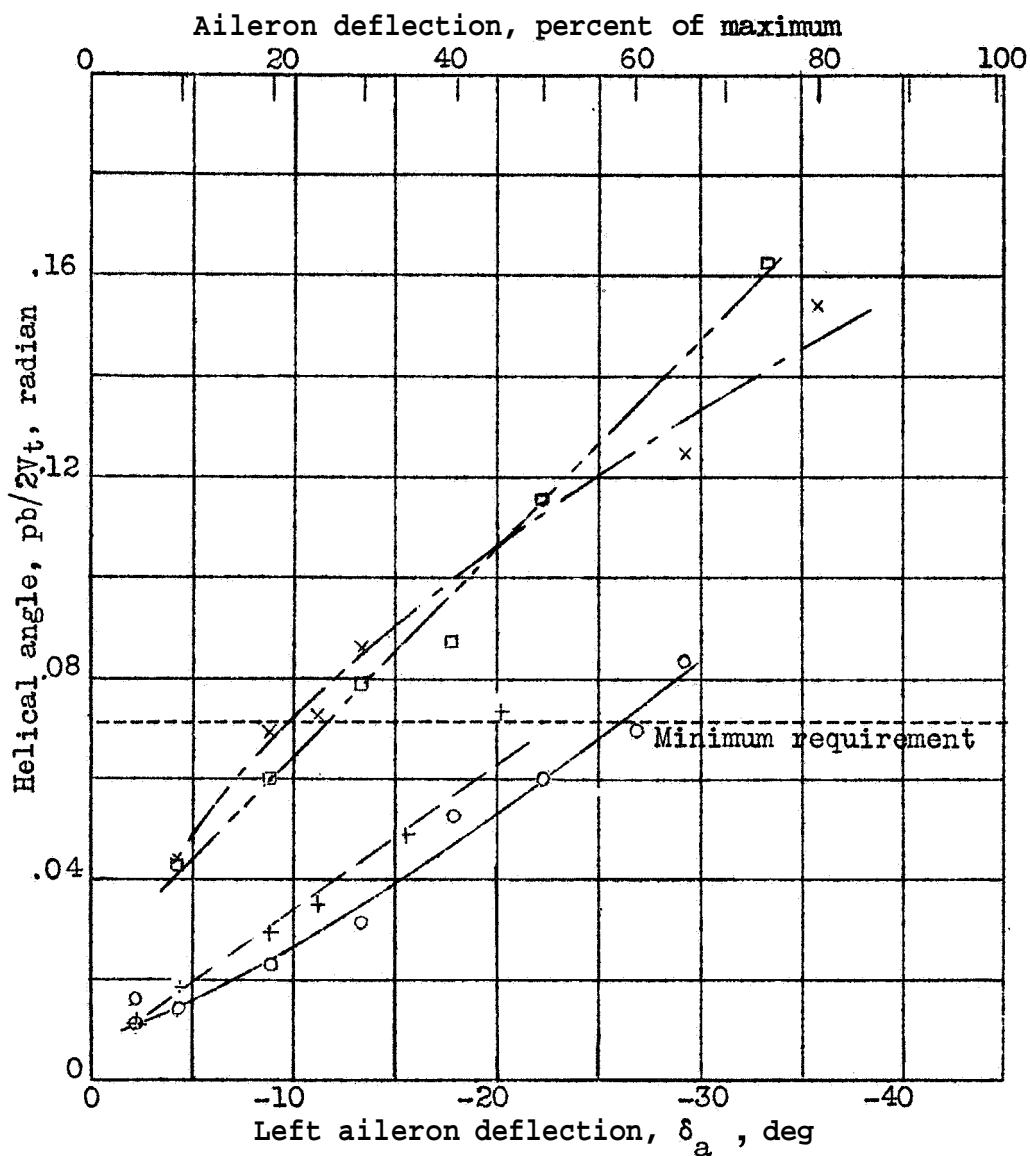test speed,
58 miles
per hour.

Fig. 20

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Figure 21.- Variation of the wing-tip helical angle with aileron
        deflection for various flap settings and airspeeds in aileron
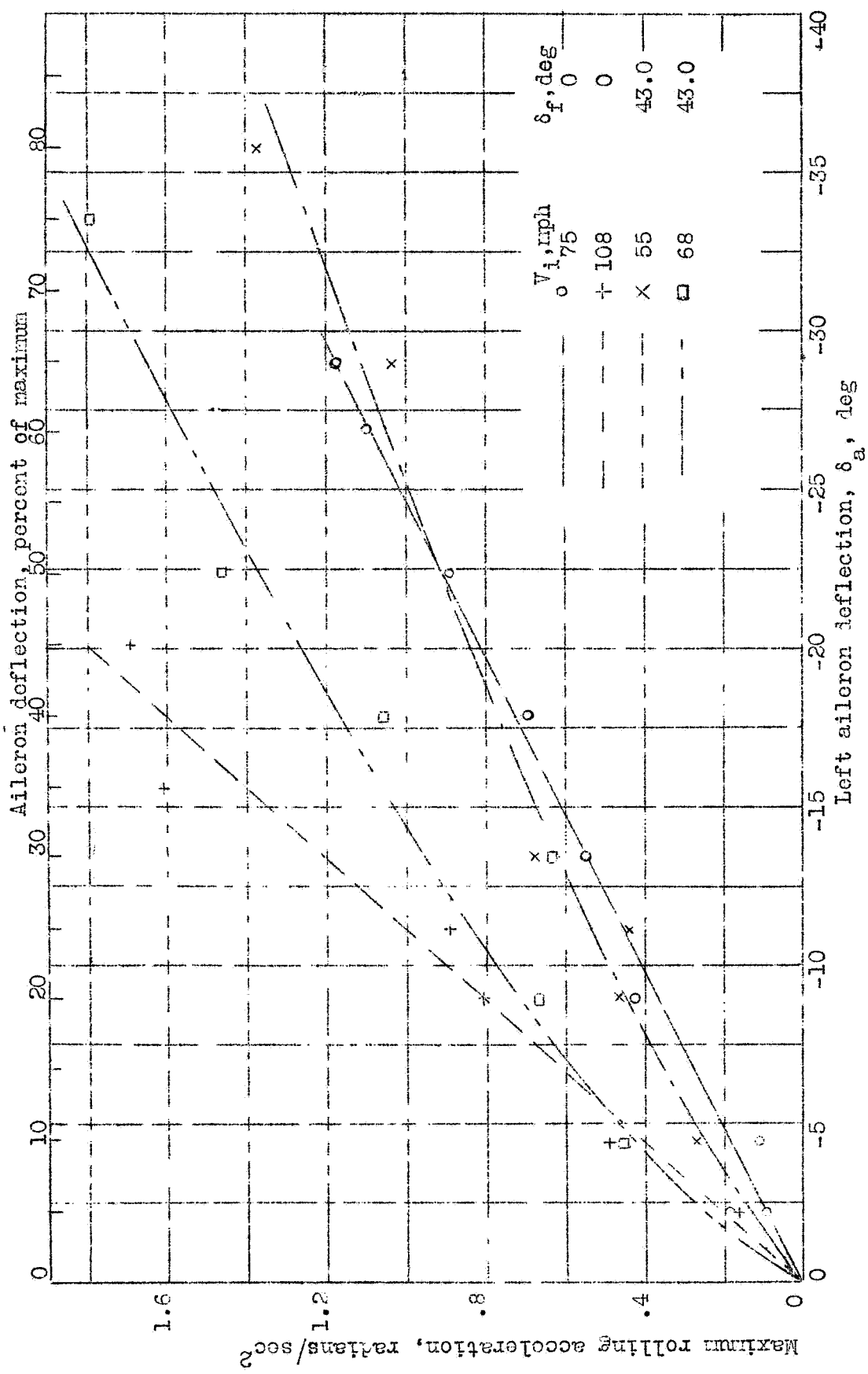rolls. Fairchild XR2K-1 airplane with Zap-flap wing installation.

Fig. 22

Figure 22.- Variation of the maximum rolling acceleration with aileron deflection for several indicated airspeeds and flap settings in abrupt aileron rolls. Fairchild XR2K-1 airplane with Zap-flap wing installation. Power on.
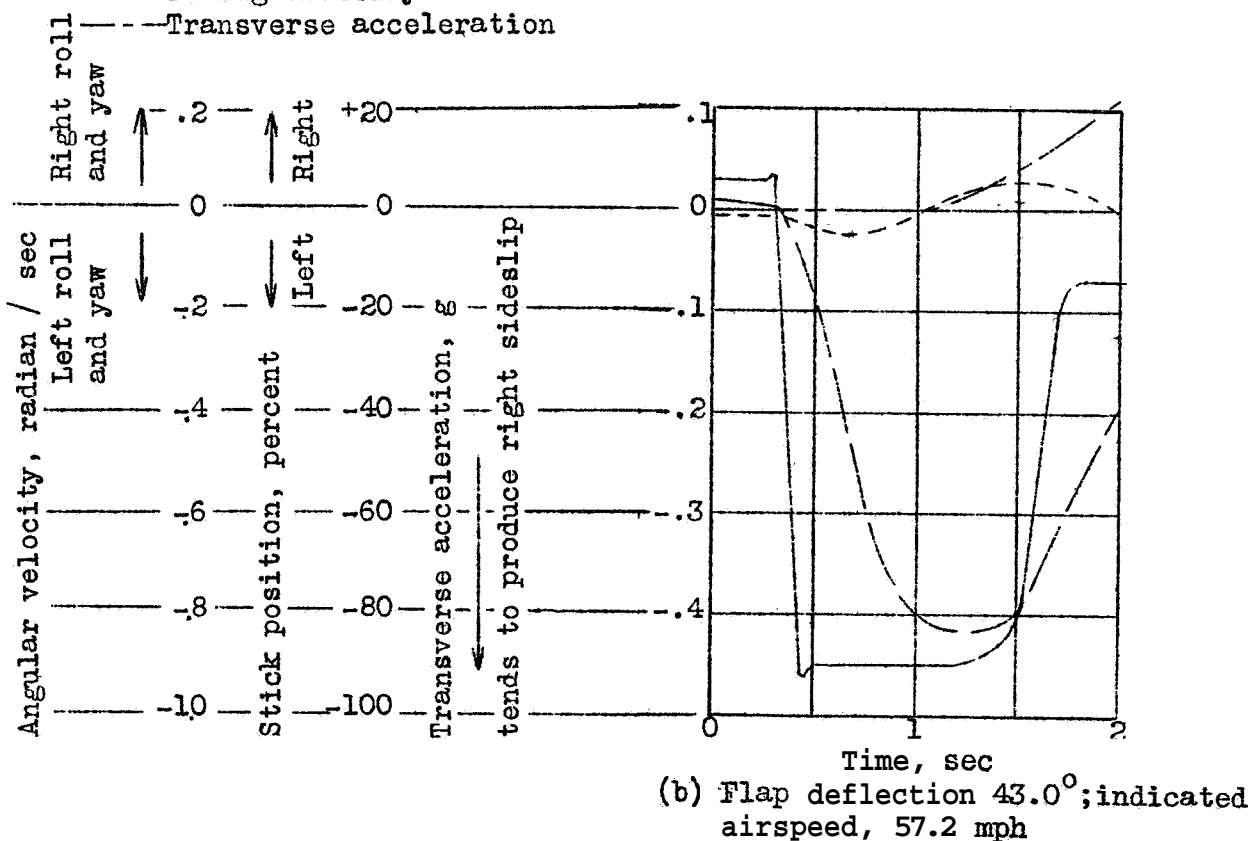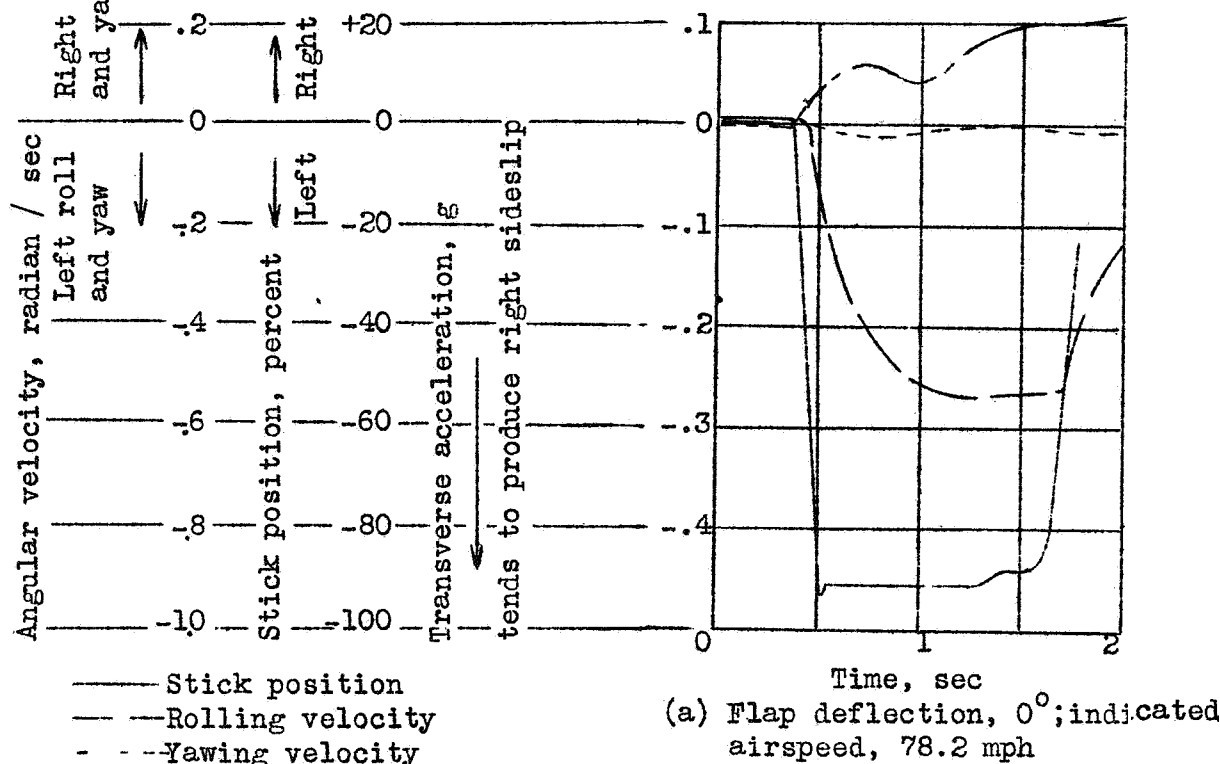
(a) Flap deflection, 0°; indicated
    airspeed, 78.2 mph

Stick position
Rolling velocity
Yawing velocity
Transverse acceleration

(b) Flap deflection 43.0°; indicated
    airspeed, 57.2 mph

Figure 23.- Time histories of abrupt left aileron rolls with particular
reference to yawing characteristics. *Rudder* and elevator
held fixed. Fairchild XR2K-1 with Zap-flap wing installation.

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Maximum initial yawing
acceleration, radian/sec^2

(a)

	δ_f, deg	V_i, mph
o	0	78.7
+	9	73.i
x	17.8	67.8
□	26.2	65.8
◇	34.3	62.8
▲	43.6	57.2

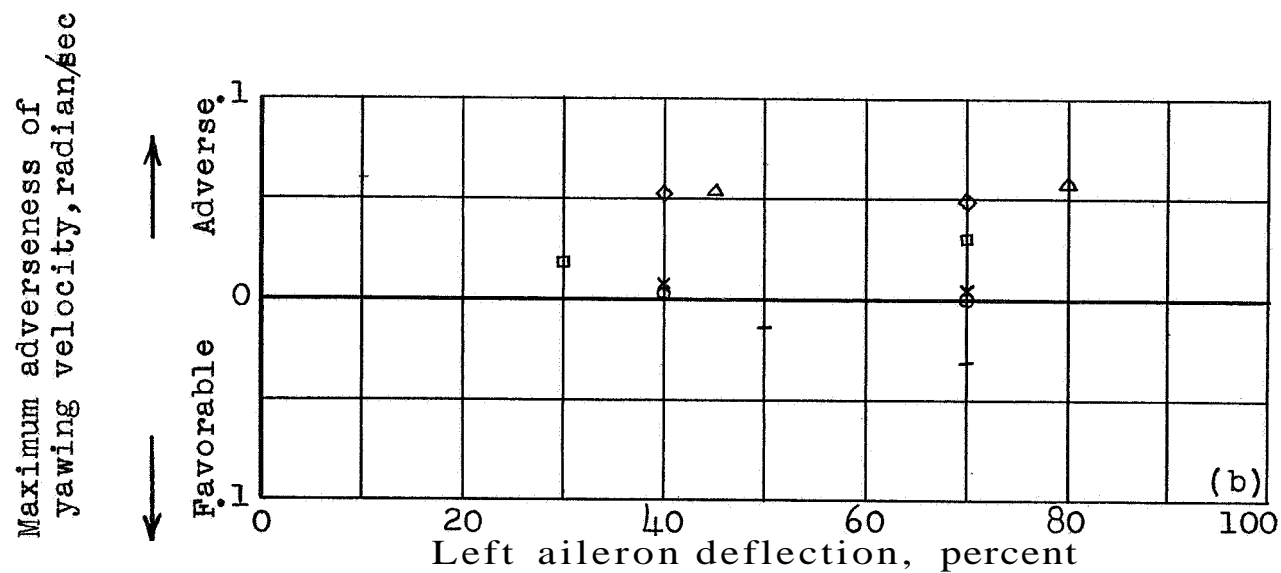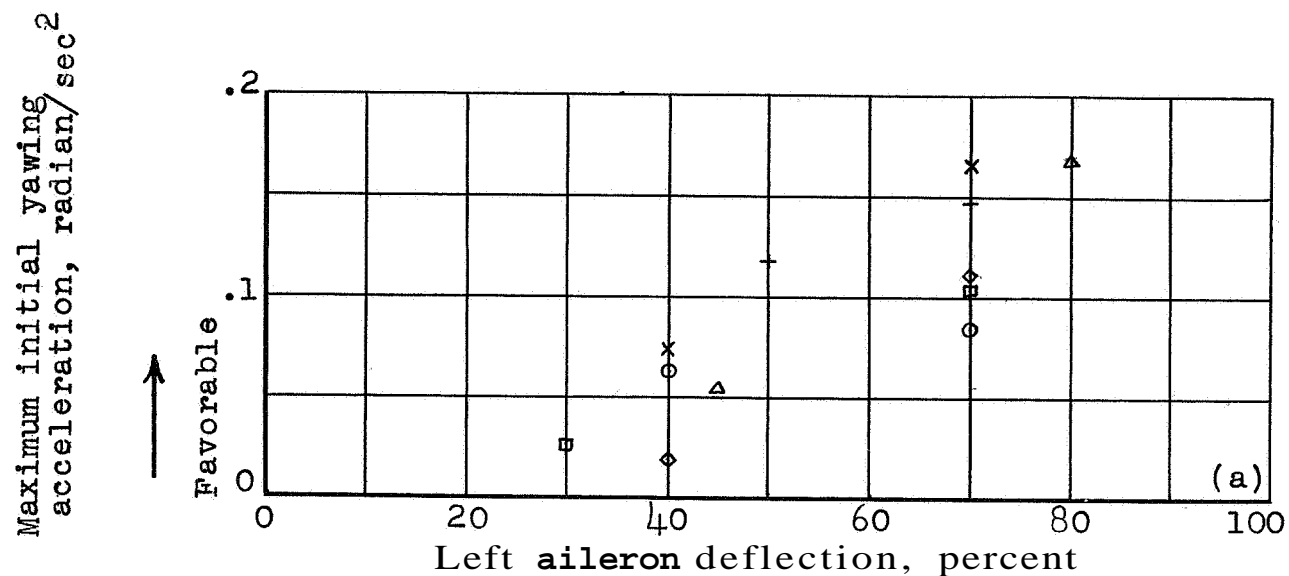Maximum adverseness of
yawing velocity,radian/sec

(b)

Figure 24.- Summary of aileron yawing characteristics on the
Fairchild XR2K-1 airplane with Zap-flap wing
installation.